

Surgeon General's Office

LIBRARY.

ANAL.

Section,

No. 20,587.

Fig. 1.

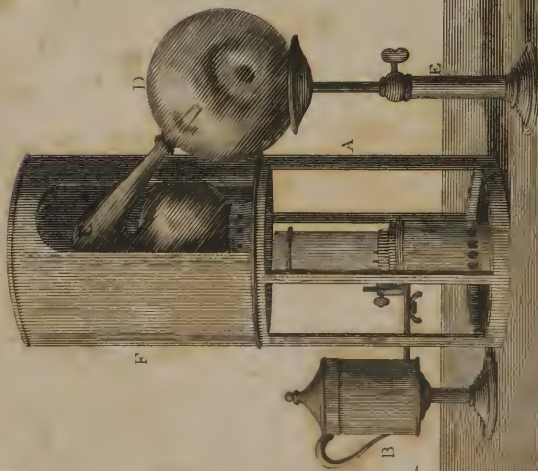


Fig. 2.

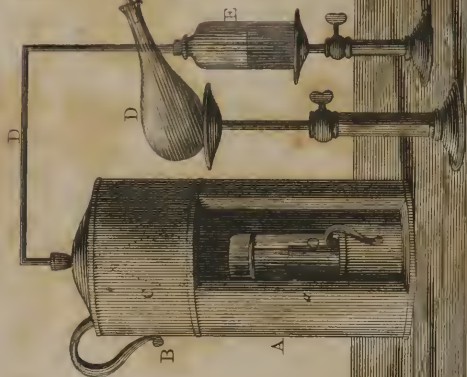
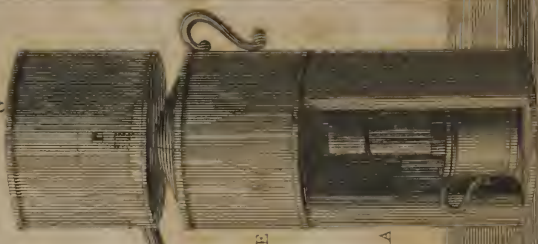
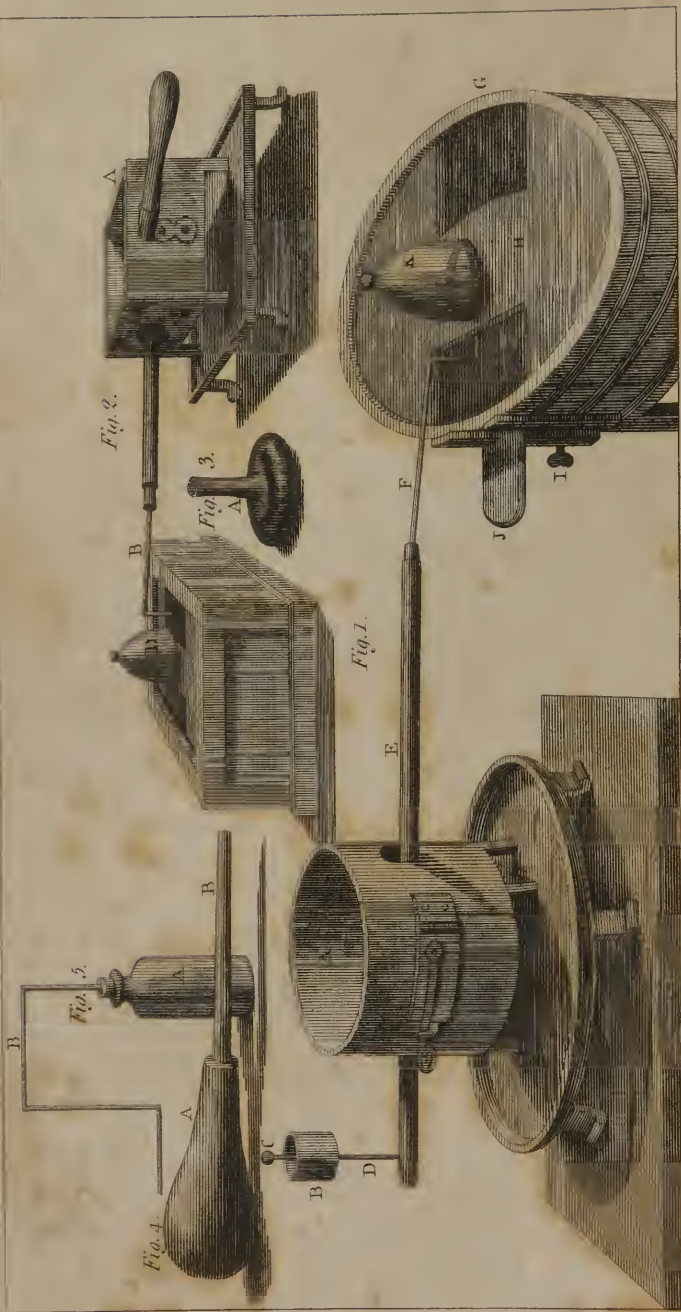


Fig. 3.



ECONOMICAL APPARATUS OF JAMES WOODHOUSE, M.D.
Professor of Chemistry, in the University of Pennsylvania &c. &c.



DR. WOODHOUSE'S ECONOMICAL APPARATUS.





ELEMENTS
OF
CHEMISTRY,

BY M. I. A. CHAPTAL,

FORMERLY CHEVALIER OF THE ORDER OF THE KING, PROFESSOR
OF CHEMISTRY AT MONTPELLIER, HONORARY INSPECTOR
OF THE MINES OF FRANCE, MINISTER OF THE IN-
TERIOR, AND MEMBER OF SEVERAL ACADE-
MIES OF SCIENCES, MEDICINE, AGRICULTURE, INSCRIPTIONS, AND
BELLES LETTRES.

The fourth American Edition, with great additions and improvements,

BY JAMES WOODHOUSE, M. D.

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF PENNSYLVANIA, &c.

VOL. I.

PHILADELPHIA:

PUBLISHED BY BENJAMIN & THOMAS KITE,
NO. 20, NORTH THIRD STREET.

SOLD ALSO BY THOMAS DOBSON, AND B. B. HOPKINS & Co. PHILADELPHIA;
HENRY CUSHING, PROVIDENCE; NATHANIEL DEARBORNE, NEW-
PORT; BEERS & HOW, NEW-HAVEN; SAMUEL WOOD, NEW-
YORK; DAVID ALLINSON, BURLINGTON; AND ZADOK
CRAMER, PITTSBURGH.

1807.

.....

BARTRAM & REYNOLDS, PRINTERS.

District of Pennsylvania, to wit :

BE IT REMEMBERED, that on the twenty-seventh day of October, in the thirty-first year of the Independence of the United States of America, A. D. 1807, Benjamin and Thomas Kite of the said District have deposited in this office the Title of a Book the right whereof they claim as proprietors in the words following, to wit :

“ Elements of Chemistry, by M. I. A. Chaptal, formerly Chevalier of the Order of the King, Professor of Chemistry at Montpellier, honorary Inspector of the Mines of France, Minister of the Interior, and Member of several Academies of Sciences, Medicine, Agriculture, Inscriptions, and Belles Lettres. The fourth American Edition, with great additions and improvements, by James Woodhouse, M. D. Professor of Chemistry in the University of Pennsylvania, &c.”

In conformity to the Act of the Congress of the United States, intituled “ An Act for the encouragement of learning, by securing the copies of Maps, Charts, and Books to the authors and proprietors of such copies during the times therein mentioned.” And also to the Act entitled “ An act supplementary to the act entitled “ An act for the encouragement of learning by securing the copies of Maps, Charts, and Books to the authors and proprietors of such copies during the times therein mentioned,” and extending the benefits thereof to the Arts of designing, engraving, and etching, historical and other prints.”

D. CALDWELL,
*Clerk of the District
of Pennsylvania.*

ADVERTISEMENT OF THE AUTHOR.

AGRICULTURE is no doubt the basis of public welfare, because it alone supplies all the wants which nature has connected with our existence. But the arts and commerce form the glory, the ornament, and the riches of every polished nation; since our refinement, and mutual dependance on each other, have created a new set of wants which require to be supplied. The cultivation of the arts is therefore become almost as necessary as that of the ground; and the true means of securing these two foundations of the reputation and prosperity of a state, consist in encouraging the Science of Chemistry, which discovers their principles. If this truth were not universally acknowledged, I might on the present occasion give an account of the success with which my labours have been attended in this province*. I might even call upon the public voice; and it would declare that, since the establishment of lectures on chemistry, between three and four hundred persons have every year derived advantage from instructions in this science. It is well known that our ancient schools of medicine and surgery, whose success and splendour are connected with the general interest of this province, are more flourishing and more numerous since that period. And with the same confidence I might appeal to the Public, that our manufactures are daily increasing in perfection; that several new kinds of industry have been introduced into Languedoc; that, in a regular succession, abuses have been reformed in the manufactories, while the processes of the arts have been simplified; that the number of coal-mines actually wrought is increased; and that upon my principles, and in consequence of my care and attention, manufactories of alum,

* Languedoc.

of oil of vitriol, of copperas, of brown red, of artificial pozzolana, of ceruse, of white lead, and others, have been established in several parts of the province.

Chemistry is therefore essentially connected with the reputation and prosperity of a state; and at this peculiar instant, when the minds of men are universally busied in securing the public welfare, every citizen is accountable to his country for all the good which his peculiar situation permits him to do. Every one ought to hasten, and present to society the tribute of those talents which heaven has bestowed on him; and there is no one who is not able to bring some materials, and deposite them at the foot of the superb edifice which the virtuous administrators are raising for the welfare of the whole. It is with these views that I have presumed to offer to my countrymen the work which I at present publish; and I entreat them to exercise their severity upon the intention of the author only, but to reserve all their indulgence to the work.

I publish these Elements of Chemistry with the greater confidence, because I have had opportunities myself of observing the numerous applications of the principles which constitute its basis to the phenomena of nature and art. The immense establishment of chemical products which I have formed at Montpellier, has allowed me to pursue the development of this doctrine, and to observe its agreement with all the facts which the various operations present to us. It is this doctrine alone which has led me to simplify most of the processes, to bring some of them to perfection, and to rectify all my ideas. It is therefore with the most intimate confidence that I propose it. I find no difficulty in making a public acknowledgment that I have for some time taught a different doctrine from that which I at present offer. I then believed it to be true and solid; but I did not on that account cease to consult nature. I have constantly entered into this research with a mind eager for improvement. Natural truths were capable of fixing themselves with all their purity in my mind, because I had banished prejudice; and insensibly I found myself drawn by the force of facts to the doctrine I now teach.

Let other principles impress the same conviction on my mind; let the same number of phenomena and facts exhibit themselves in their favour; the same number of happy applications to the operations of nature and of art; let them appear to my mind with all the sacred characters of truth; and I will publish them with the same zeal and with the same interest. I condemn equally the man who, attached to the ancient notions, respects them so much as to reject without mature examination every thing which appears to oppose them; and him who embraces with enthusiasm, and almost without reflection, the principles of any new doctrine. Both are worthy of compassion if they grow old in their prejudices; and both are worthy of blame if they perpetuate them.

I have been careful to banish all discussions from my work. That spirit of party which but too often causes a division between persons who are pursuing the same objects, that tone of bitterness which predominates in certain disputes, that want of candour which is insensibly produced by the movements of self-love, have but too long retarded the progress of our knowledge. The love of truth is the only passion which a philosopher ought to indulge. The same object, the same interest, tend to unite chemists. Let the same spirit inspire them, and direct all their labours. Then we shall soon behold chemistry advancing in a rapid progress; and its cultivators will be honoured with the suffrage and the gratitude of their countrymen.

I have endeavoured in this work to explain my ideas with clearness, precision, and method. I know by experience that the success of any work, and its various degrees of utility, often depend on the form under which the doctrine which it contains is displayed; and it has accordingly been my intention to spare no pains in exhibiting the truths which form the basis of this work in all the characters they are justly entitled to.

In composing these Elements of Chemistry, I have availed myself with advantage of all the facts which I have found in the works of the celebrated chemists who

adorn this age. I have even made no scruple to follow their method in drawing up certain articles; and have transferred into my own work, almost without alteration, those facts which I have elsewhere found described with a greater degree of precision and perspicuity than I might have been capable of bestowing on them. This proceeding, in my opinion, renders homage to authors instead of robbing them. If such a proceeding might justify reclamations, Messrs. Lavoisier, De Morveau, Berthollet, De Fourcroy, Sage, Kirwan, &c. might easily declare against me.

I was well aware that the pretension of knowing, discussing and methodically distributing the whole of our present science of chemistry, was an enterprise beyond my ability. This science has made so great a progress, and its applications are so multiplied, that it is impossible to attend to the whole with the same care: and it appears to me that the writer of an elementary work ought at present to attend principally to the development of general principles, and content himself in pointing out the consequences, and their applications. In this way of proceeding we shall follow the method which has long been practised in the study of the mathematics; the principles of which, nearly insulated, and separated from all application, form the first study of him who means to acquire them.

To obtain a thorough acquaintance with all the knowledge which has been acquired in chemistry until our time, the chemical part of the *Encyclopédie Méthodique* may be consulted. In this work, the celebrated author gives the most interesting account of the progress of the science. Here it is that he discusses the several opinions with that candour and energy which become the man of letters whose mind is directed to truth only. Here it is that he has made a precious deposit of all the knowledge yet acquired, in order to present to us in the same point of view all which has been done, and all which remains to be done: and here, in a word, it is that Mr. De Morveau has rendered the most striking homage to the truth of the doctrine we now teach; because, after having combated some of its principles in the first volume, he has had the

courage to recant the moment the facts seen in a better point of view, and repeated experiments, had sufficiently enlightened him. This great example of courage and candour is doubtless honourable to the learned man who gives it; but it cannot fail to add still more to the confidence which may be placed in the doctrine which is its object.

The development of the principles upon which the New Nomenclature is established, may be found in the Elementary Treatise of Chemistry of Mr. Lavoisier; and I refer likewise to this excellent work for the figure and explanation of all the apparatus I shall have occasion to speak of. I take this step the more earnestly, because, by associating my own productions to those of this celebrated chemist, I entertain the hope of securing their success, and can deliver them into the hands of the public with the greater confidence.

CONTENTS.

PART FIRST.

CONCERNING THE CHEMICAL PRINCÍPLES.

INTRODUCTION.

	Page.
D EFINITION of Chemistry; its Object and Means.—	
Description of a Laboratory, and the principal Instruments employed in chemical Operations, with a Definition of those Operations	29

SECTION I.

Concerning the General Law which tends to bring the Particles of Bodies together, and to maintain them in a State of Mixture or Combination	42
Of the Affinity of Aggregation	43
Of the Affinity of Composition	45

SECTION II.

Concerning the various Means employed by Chemists to over- come the Adhesion which exists between the Particles of Bodies	54
---	----

SECTION III.

Concerning the Method of Proceeding which the Chemist ought to follow in the Study of the various Bodies presented to us by Nature	57
--	----

SECTION IV.

Concerning Simple or Elementary Substances	64
Chap. I. Concerning Fire	65
Art. I. Concerning Caloric and Heat	66
Art. II. Concerning Light	78
Chap. II. Concerning Sulphur	84
Chap. III. Concerning Carbone	88

SECTION V.

Concerning Gases, or the Solution of certain Principles in Caloric at the Temperature of the Atmosphere	90
VOL. I.	b

Chap. I. Concerning the Hydrogenous Gas, or Inflam- mable Air	Page. 93
Chap. II. Concerning Oxygenous Gas, or Vital Air	99
Chap. III. Concerning Nitrogene Gas, Azote, or Atmosph- rical Mephitis	114

SECTION VI.

Concerning the Mixture of Nitrogene and Oxigene Gas ; or of Atmospheric Air	116
--	-----

SECTION VII.

Concerning the Combination of Oxygenous Gas and Hydrogene, which forms Water	118
Art. I. Concerning Water in the State of Ice	120
Art. II. Concerning Water in the Liquid State	122
Art. III. Concerning Water in the State of Gas	125

SECTION VIII.

Concerning the Combinations of Nitrogene Gas. 1. With Hy- drogene Gas. 2. With the Earthy Principles forming the Alkalis	130
Chap. I. Concerning Fixed Alkalis	131
Art. I. Concerning the Vegetable Alkali, or Potash	ibid.
Art. II. Concerning the Mineral Alkali, or Soda	134
Chap. II. Concerning Ammoniac, or the Volatile Alkali	138

SECTION IX.

Concerning the Combination of Oxigene with certain Bases forming Acids	142
Chap. I. Concerning the Carbonic Acid	146
Art. I. Carbonate of Potash	152
Art. II. Carbonate of Soda	153
Art. III. Carbonate of Ammoniac	154
Chap. II. Concerning the Sulphuric Acid	156
Art. I. Sulphate of Potash	161
Art. II. Sulphate of Soda	162
Art. III. Sulphate of Ammoniac	164
Chap. III. Concerning the Nitric Acid	166
Art. I. Nitrate of Potash	172
Art. II. Nitrate of Soda	178
Art. III. Nitrate of Ammoniac	ibid.
Chap. IV. Concerning the Muriatic Acid	179
Art. I. Muriate of Potash	190
Art. II. Muriate of Soda	191
Art. III. Muriate of Ammoniac	195
Concerning Oxide of Carbone	155
Oximuriate of Potash	187

	Page.
Chap. V. Concerning the Nitro-muriatic Acid	197
Chap. VI. Concerning the Acid of Borax	199
Art. I. Borate of Potash	202
Art. II. Borate of Soda	ibid.
Art. III. Borate of Ammoniac	206

PART SECOND.

CONCERNING LITHOLOGY; OR AN ACCOUNT OF STONY SUBSTANCES.

INTRODUCTION	207
Lime	211
Barytes, or Ponderous Earth	213
Magnesia, or Magnesian Earth	212
Alumine, or Pure Clay	215
Silex, or Quartzose Earth, Vitriifiable Earth, &c.	216
Strontites	214
Zirconia	217
Glucina	ibid.
Yttria	216
Agustina	218

CLASS I.

Concerning the Combination of Earths with Acids	217
---	-----

GENUS I.

Earthly Salts with Basis of Lime	218
Spec. I. Carbonate of Lime, or Calcareous Stone	219
Crystallized Calcareous Stones	220
Calcareous Stones which are not crystallized	221
The Analysis and Uses of Calcareous Stone	226
Spec. II. Sulphate of Lime, Gypsum, Selenite, Plaster Stone	230
Spec. III. Fluuate of Lime, Vitreous Spar, Fusible or Phosphoric Spar, Fluor Spar	234
Spec. IV. Nitrate of Lime, Calcareous Nitre	237
Spec. V. Muriate of Lime, Calcareous Marine Salt	238
Spec. VI. Phosphate of Lime, Calcareous Phosphoric Salt	ibid.

GENUS II.

Earthly Salts with Base of Barytes	239
Spec. I. Sulphate of Barytes, Ponderous Spar	ibid.
Spec. II. Carbonate of Barytes	241
Spec. III. Nitrate of Barytes	242
Spec. IV. Muriate of Barytes	ibid.

GENUS III.

	Earthy Salts with Basis of Magnesia	242
Spec. I.	Sulphate of Magnesia, Epsom Salt	243
Spec. II.	Nitrate of Magnesia	244
Spec. III.	Muriate of Magnesia	ibid.
Spec. IV.	Carbonate of Magnesia	245

GENUS IV.

	Earthy Salts with Base of Alumine, Alum	246
Spec. I.	Sulphate of Alumine, Alum	ibid.
Spec. II.	Carbonate of Alumine	249

GENUS V.

	Earthy Salts with Base of Silex	250
--	---------------------------------	-----

CLASS II.

Concerning the Combination and Mixture of Primitive Earths, or Earthy Mixtures	250
---	-----

GENUS I.

	Calcareous Mixtures	251
Spec. I.	Lime-stone and Magnesia	ibid.
Spec. II.	Lime-stone and Barytes	252
Spec. III.	Carbonate of Lime and Alumine	ibid.
Spec. IV.	Lime-stone and Silex	253
Spec. V.	Lime-stone and Bitumen	ibid.
Spec. VI.	Lime-stone and Iron	254

GENUS II.

	Barytic Mixtures	254
Spec. I.	Sulphate of Barytes, Petroleum, Gypsum, Alum, and Silex—Bergmanni Sciagr. s. 90 ; Kirwan Min. p. 60	255
Spec. II.	Carbonate of Barytes, Iron and Silex	ibid.

GENUS III.

	Magnesian Mixtures	255
Spec. I.	Pure Magnesia, Silex, and Alumine	256
Spec. II.	Carbonate of Magnesia, Silex, and Alumine	ibid.

	Page.
Spec. III. Pure Magnesia combined with somewhat more than its Weight of Silex, one-third of Alumine, near one-third of Water, and more or less of Iron	258
Spec. IV. Carbonate of Magnesia; Silex, Lime, Alumine and Iron	259
Variety I. Asbestos	260
Variety II. Mountain Cork	ibid.
Spec. V. Carbonate of Magnesia and Lime, Sulphate of Barytes, Alumine and Iron	261

GENUS IV.

Aluminous Mixtures	262
Spec. I. Alumine, Silex, Carbonate of Lime and more or less of Iron	ibid.
Spec. II. Alumine, Silex, Pure Magnesia, and Iron	268
Spec. III. Alumine, Silex, Magnesia, Lime, and Iron	269
Variety I. Black Horn-stone, Lapis Corneus Nitens Wallerii	ibid.
Variety II. Horn-stone of a Greenish Grey Colour	270
Spec. IV. Alumine, Silex, Carbonate of Magnesia, and of Lime with Iron	ibid.
Variety I. Blueish Purple Slate	ibid.
Variety II. Black Slate	271
Variety III. Blue Slate	ibid.
Variety IV. Slate of a Pale white Colour	272
Spec. V. Alumine, Silex, Pyrites or Sulphure of Iron, and Carbonate of Lime and of Magnesia	ibid.
Spec. VI. Alumine, Silex, the Carbonates of Lime and of Magnesia, the Sulphure of Iron and Bitumen	273
Spec. VII. Alumine, Silex, Lime, and Water	274

GENUS V.

Siliceous Mixtures	275
Spec. I. Silex, Alumine, Lime, and Iron, intimately combined,	ibid.
Division I. Red Gems, or Precious Stones—the Ruby, Garnet, &c.	276
Division II. Yellow Gems or Precious Stones—the Topaz, the Hyacinth, &c.	277
Division III. Green Gems—the Emerald, Chrysolite, Beryl, &c.	279
Division IV. Blue Gems—Sapphire	281
Spec. II. Silex, sometimes pure, but oftener mixed with a very small Quantity of Alumine, Lime, and Iron	282
Division I. Rock Crystal	ibid.
Variety I. Red Crystal—False Ruby	284
Variety II. Yellow Crystal—Bohemian Topaz	285
Variety III. Brown Crystal—Smoky Topaz	ibid.
Variety IV. Green Crystal—False Emerald	ibid.
Variety V. Blue Crystal—Water Sapphire	ibid.

	Page.
Variety VI. Violet Crystal—the Amethyst	286
Division II. Quartz	ibid.
Spec. III. Silix, Alumine, Lime, and Iron, intimately mixed	287
Division I. The Coarser Flints	ibid.
Division II. The Finer Flints	288
Spec. IV. Silix, Alumine, and Iron	291
Spec. V. Silix, Alumine, Lime, with a small Portion of Magnesia and Iron	292
Spec. VI. Silix, Lime, Magnesia, Iron, Copper, and the Fluoric Acid	300
Spec. VII. Silix, the Blue Fluat of Lime, with the Sulphate of Lime or Iron	303
Spec. VIII. Silix, Alumine, Barytes, and Magnesia	305

CLASS III.

Concerning the Mixture of Stones among each other.	Stony
Mixtures. Rocks	307

GENUS I.

Rocks formed by the Mixture of Calcareous Stones with other Species	308
Spec. I. Carbonate of Lime, and Sulphate of Barytes	ibid.
Spec. II. Carbonate of Lime and Mica	ibid.
Spec. III. Mixtures of Calcareous and Magnesian Stones	ibid.
Spec. IV. Calcareous Stones, and Fragments of Quartz	309

GENUS II.

Compound Stones formed by the Mixture of Barytic Stones with other Stones	309
Spec. I. Ponderous Spar mixed with a small Quantity of Calcareous Spar	310
Spec. II. Ponderous Spar and Serpentine	ibid.
Spec. III. Ponderous Spar and Fluor Spar	ibid.
Spec. IV. Ponderous Spar and Indurated Clay	ibid.
Spec. V. Ponderous Spar and Quartz	311
Spec. VI. Ponderous Spar and Lava	ibid.

GENUS III.

Rocks or Stones formed by the Mixture of Magnesian Stones with other Kinds	311
Spec. I. Magnesian Stones mixed together	ibid.
Spec. II. Magnesian Stones and Calcareous Stones	ibid.
Spec. III. Magnesian Stones and Aluminous Stones	312
Spec. IV. Magnesian Stones and Siliceous Stones	ibid.

GENUS IV.

Rocks or Stones formed by the Mixture of Aluminous Stones with other Species	- - - - -	312
Spec. I. Schistus and Mica	- - - - -	ibid.
Spec. II. Schistus and Garnet	- - - - -	313
Spec. III. Schistus, Mica, and Quartz mixed in small Fragments	- - - - -	ibid.
Spec. IV. Schistus and Schorl	- - - - -	314
Spec. V. Clay and Quartz	- - - - -	ibid.

GENUS V.

Compound Stones formed by the Mixture and of Re-union of Quartzose Stones with each other	- - - - -	315
Spec. I. Quartz and Schorl	- - - - -	ibid.
Spec. II. Quartz and Feld Spar	- - - - -	316
Spec. III. Grit-stone and Garnet	- - - - -	ibid.
Spec. IV. Quartz, Feld Spar, and Schorl	- - - - -	ibid.
Spec. V. Fragments of Quartz united by a Siliceous Cement	- - - - -	317
Spec. VI. Jasper and Feld Spar	- - - - -	ibid.
Spec. VII. Jasper and Garnet	- - - - -	318
Spec. VIII. Jasper and Calcedony	- - - - -	ibid.
Spec. IX. Jasper and Quartz	- - - - -	319
Spec. X. Jasper, Quartz, and Feld Spar	- - - - -	ibid.
Spec. XI. Schorl, Garnet, and Tourmaline	- - - - -	ibid.

GENUS VI.

Super-compound Stones, or such as result from the Mixture and Re-union of several different Genera	- - - - -	320
Spec. I. Petrosilex, Alumine, and Calcareous Spar	- - - - -	ibid.
Spec. II. Clay, Steatites, and Calcareous Spar	- - - - -	ibid.
Spec. III. Clay, Zeolite, Schorl, and Calcareous Spar	- - - - -	ibid.
Spec. IV. Clay, Serpentine, and Calcareous Spar	- - - - -	ibid.
Spec. V. Serpentine, Mica, and Calcareous Spar	- - - - -	ibid.
Spec. VI. Serpentine, Schorl, and Calcareous Stone	- - - - -	321
Spec. VII. Steatites, Mica, and Garnets	- - - - -	ibid.
Spec. VIII. Steatites, Mica, and Schorl	- - - - -	ibid.
Spec. IX. Garnets, Quartz, Mica, and Serpentine	- - - - -	ibid.
Spec. X. Feld Spar, Quartz, Mica, Steatites	- - - - -	ibid.
Spec. XI. Quartz, Mica, and Clay	- - - - -	ibid.
Spec. XII. Quartz, Clay, and Steatites	- - - - -	322
Concerning the Diamond	- - - - -	ibid.

<i>General Views respecting the Decompositions and Changes to which the Stony Part of our Globe has been Subjected.</i>	- - - - -	326
---	-----------	-----



PRELIMINARY DISCOURSE.

IT appears that the ancient nations possessed some notions of chemistry. The art of working metals, which dates from the most remote antiquity; the lustre which the Phœnicians gave to certain colours; the luxury of Tyre; the numerous manufactures which that opulent city included within its walls—all announce a degree of perfection in the arts, and suppose a considerable extent and variety of chemical knowledge. But the principles of this science were not then united into a body of doctrine; they were concentrated in the workshops of the manufactures, where they had their origin: and observations alone, transmitted from one operator to another, enlightened and conducted the steps of the artists. Such, no doubt, has been the origin of all the sciences. At first they presented unconnected facts; truths were confounded with error; time and genius alone could clear up the confusion; and the progress of information is always the fruit of slow and painful experiment. It is difficult to point out the precise epocha of the origin of chemical science; but we find traces of its existence in the most remote ages. Agriculture, mineralogy, and all the arts which are indebted to it for their principles, were cultivated and enlightened. We behold the original nations, immediately succeeding the fabulous ages, surrounded by all the arts which supplied their wants; and we may compare chemistry to that famous river whose waters fertilize the lands they inundate, but whose sources are still to us unknown.

Egypt, which appears to have been the nurse of chemistry reduced to principles, was not slow in turning the

applications of this science towards a chimerical end. The first seeds of chemistry were soon changed by the passion of making gold. In a moment all the labours of operators were directed towards alchemy alone; the great object of study became fixed on an endeavour to interpret fables, allusions, hieroglyphics, &c.; and the industry of several centuries was consecrated to the inquiry after the philosopher's stone. But though we admit that the alchemists have retarded the progress of chemistry, we are very far from being disposed to any outrage on the memory of these philosophers: we allow them the tribute of esteem to which on so many accounts they are entitled. The purity of their sentiments, the simplicity of their manners, their submission to Providence, and their love for the Creator, penetrate with veneration all those who read their works. The profoundest views of genius are every where seen in their writings, allied with the most extravagant ideas. The most sublime truths are degraded by applications of the most ridiculous nature; and this astonishing contrast of superstition and philosophy, of light and darkness, compels us to admire them, even at the instant that we cannot withhold our censure. We must not confound the sect of alchemists, of whom we shall proceed to speak, with that crowd of impostors, that sordid multitude of operators at the furnace, whose researches were directed to the discovery of minds capable of being imposed upon, who fed the ambition of such weak minds by the deceitful hope of increasing their riches. This last class of vile and ignorant men has never been acknowledged by the true alchemists; and they are no more entitled to that name, than the vender of specifics on the stage to the honourable name of Physician.

The hope of the alchemist may indeed be founded on a slender basis; but the great man, the man of genius, even at the time when he is pursuing an imaginary object, knows how to profit by the phenomena which may present themselves, and derives from his labours many useful truths which would have escaped the penetration of ordinary men. Thus it is that the alchemists have successively enriched pharmacy and the arts with most of their compositions. The strong desire of acquiring riches has in all times been a passion so general, that this single mo-

tive has been sufficient to lead many persons to the cultivation of a science which has more relation than any other to metals; which studies their nature more particularly, and appears to facilitate the means of composing them. It is known that the Abdarites did not begin to consider the sciences as an occupation worthy a reasonable man, until they had seen a celebrated philosopher enrich himself by speculations of commerce; and I do not doubt but that the desire of making gold has decided the vocation of several chemists. We are therefore indebted to alchemy for several truths, and for several chemical professors: but this obligation is small in comparison to the mass of useful truth which might have been afforded during the course of several centuries; if, instead of endeavouring to form the metals, the operations of chemists had been confined to analyzing them, simplifying the means of extracting them, combining them together, working them, and multiplying and rectifying their uses.

The rage for making gold was succeeded by the seductive hope of prolonging life by means of chemistry. The persuasion was easily admitted, that a science which affords remedies for all disorders, might without effort succeed in affording a universal medicine. The relations which have been handed down to us of the long life of the ancients, appeared to be a natural effect of their knowledge in chemistry. The numerous fables of antiquity obtained the favour of being admitted among established facts; and the alchemists, after having exhausted themselves in the search after the philosopher's stone, appeared to redouble their efforts to arrive at an object still more chimerical. At this period the elixirs of life, the arcana, the polychrest medicines, had their origin; together with all those monstrous preparations, of which a few have been handed down even to our days.

The chimera of the universal medicine agitated the minds of most men in the sixteenth century; and immortality was then promised with the same effrontery as a Charlatan now announces his remedy for every disease. The people are easily seduced by these ridiculous promises; but the man of knowledge can never be led to think that chemistry can succeed in reversing that general law of nature which condemns all living beings to re-

novation, and a continual circulation of decompositions and successive generations. This sect gradually became an object of contempt. The enthusiast Paracelsus, who, after having flattered himself with immortality, died at the age of forty-eight at an inn at Saltsburg, completed its disgrace. From that moment the scattered remains of this sect united themselves, never more to appear again in public. The light which began to shine forth on all sides, rendered it necessary that they should have recourse to secrecy and obscurity; and thus at length chemistry become purified.

James Barner, Bohnius, Tachenius, Kunckel, Boyle, Crollius, Glaser, Glauber, Schroder, &c. appeared on the ruins of these two sects, to examine this indigested aggregate, and separate from the confused mass of phenomena, of truth and of error, every thing which could tend to enlighten the science. The sect of the adepts, urged on by the madness of immortality, had discovered many remedies; and pharmacy and the arts then became enriched with formulæ and compositions, whose operations required only to be rectified, and their applications better estimated.

Nearly at the same time appeared the celebrated Becher. He withdrew chemistry from the too narrow limits of pharmacy. He shewed its connexion with all the phenomena of nature; and the theory of the formation of metals, the phenomena of fermentation, the laws of putrefaction, were all comprehended and developed by this superior genius. Chemistry was then directed to its true object: and Stahl, who succeeded Becher, reduced to certain general principles all the facts with which his predecessor had enriched the science. He spoke a language less enigmatical; he classed all the facts with order and method; and purged the science of that alchemic infection, to which Becher himself was too much attached. But if we consider how great are the claims of Stahl, and how few the additions which have been made to his doctrine until the middle of this century, we cannot but be astonished at the small progress of the science. When we consult the labours of the chemists who have appeared since the time of Stahl, we see most of them chained down to the steps of this great man, blindly subscribing to all

his ideas; and the labour of thinking appeared no longer to exist among them. Whenever a well-made experiment threw a gleam of light unfavourable to his doctrine, we see them torment themselves in a ridiculous manner to form a delusive interpretation. Thus it was that the increase of weight which metals acquire by calcination, though little favourable to the idea of the subtraction of a principle without any other addition, was nevertheless incapable of injuring this doctrine.

The almost religious opinion which enslaved all the chemists to Stahl, has no doubt been pernicious to the progress of chemistry. But the strong desire of reducing every thing to first principles, and of establishing a theory upon incomplete experiments, or facts imperfectly seen, did not admit of the smallest obstacles. From the moment that analysis had shewn some of the principles of bodies, the chemist thought himself in possession of the first agents of nature. He considered himself as authorized to regard those bodies as elements which appeared no longer susceptible of being decomposed. The acids and the alkalis performed the principal part in natural operations; and it appeared to be a truth buried in oblivion, that the term where the artist stops is not the point at which the Creator has limited his power; and that the last result of analysis does indeed mark the limits of art, but does not fix those of nature. We might likewise reproach certain chemists for having too long neglected the operations of the living systems. They confined themselves in their laboratories, studied no bodies but in their lifeless state, and were incapable of acquiring any knowledge but such as was very incomplete: for he who, in his researches, has no other object in view than that of ascertaining the principles of a substance, acts like a physician who should suppose he had acquired a complete notion of the human body by confining his studies to the dead carcass. But we must likewise observe that, in order to form a proper notion of the phenomena of living bodies, it is necessary to possess the means of confining the gaseous principles which escape from bodies; and of analyzing these volatile and invisible substances which combine together. Now this work was impossible at that time; and we

ought to beware of imputing to men those errors which arise from the state of the times in which they lived.

It may perhaps be demanded, on this occasion, why chemistry was sooner known, and more generally cultivated, in Germany and in the North than in our kingdom. I think that many reasons may be given for this. In the first place, the scholars of Stahl and of Becher must have been more numerous, and consequently their instruction farther extended. Secondly, the working of mines having become a resource necessary to the governments of the North, has been singularly encouraged; and that chemistry which enlightens mineralogy must necessarily have participated in its encouragements*.

The study of chemistry did not begin to be cultivated to advantage in France until the end of the last century. The first wars of Louis XIV. so proper to develop the talents of the artist, the historian, and the military man, appeared little favourable to the peaceable study of nature. The naturalist, who in his researches sees union and harmony around him, cannot be an indifferent spectator of the continual scenes of disorder and destruction; and his genius is crushed in the midst of troubles and agitations. The mind of the great Colbert, deeply penetrated with these truths, quickly endeavoured to temper the fire of discord, by turning the minds of men towards the only objects which could secure the peace and

* Since the French government has facilitated the study of mineralogy by the most superb establishments, we have beheld the taste for chemistry revive, the arts which have the working of metals for their object have been rendered more perfect, and the mines which have been wrought are more numerous. Mr. Sage has been more particularly assiduous and zealous to turn the favour of government towards this object. I have been a witness to the laborious attention of this chemist to effect this revolution. I have beheld the personal sacrifices he made to bring it forward. I have applauded his zeal, his motives, and his talents. The same sentiments still occupy my mind; and though I teach a doctrine at present which is different from his, this circumstance arises from the impossibility of commanding opinions. The philosopher who is truly worthy of this name, is capable of distinguishing the friend of his heart from the slave of his system: and, in a word, every one ought to write according to his conviction; the most sacred axiom of the sciences being "*Amicus Plato, sed magis amica veritas.*"

prosperity of the state. He exerted himself to render trade flourishing: he established manufactories: learned men were invited from all parts, encouraged, and united together, to promote his vast projects. Then it was that the ardour of inquiry replaced for a time the fury of conquest; and France very soon stood in competition with all nations for the rapid progress of the sciences, and the perfection of the arts. Lemery, Homberg, and Geoffroy arose nearly at the same time; and other nations were no longer entitled to reproach us for the want of chemists. From that moment the existence of the arts appeared to be well assured. All the sciences which afford their first principles, were cultivated with the greatest success: and it will scarcely be credited that, in the space of a few years, the arts were drawn from a state of non-entity; and carried to such a degree of perfection, that France, which had before received every thing from foreign countries, became in possession of the glory of supplying its neighbours with models and with merchandises.

Chemistry and natural history, however, at the beginning of this century, were cultivated only by a very small number of persons; and it was then thought that the study of these sciences ought to be confined to the academies. But two men, whose names will be ever famous, have rendered the taste general under the reign of Louis XV. The one possessed that noble spirit which is a stranger to the power of prejudice, that indefatigable ardour which so easily overcomes every obstacle, that openness of character which inspires confidence, and transfused into the minds of his pupils that enthusiasm of which he himself felt the force. While Rouelle enlightened the science of chemistry, Buffon prepared a revolution still more astonishing in natural history. The naturalists of the North had succeeded in causing their productions to be read by a small number of the learned; but the works of the French naturalist were soon, like those of nature, in the hands of the whole world. He possessed the art of diffusing through his writings that lively interest, that enchanting colouring, and that delicate and vigorous touch, which influence, attach, and subdue the mind. The profundity of his reasoning is

every where united to all that agreeable illusion which the most brilliant imagination can furnish. The sacred fire of genius animates all his productions; his systems constantly exhibit the most sublime prospects in their totality, and the most perfect correspondence in their minute parts: and, even when he exhibits mere hypotheses, we are inclined to persuade ourselves that they are established truths. We become like the artist who, after having admired a beautiful statue, used his efforts to persuade himself that it respired, and removed every thing which could dissipate his illusion. We take up his work with a pleasure resembling that of the man who turns again to sleep, in hopes of prolonging the deception of an agreeable dream.

These two celebrated men, by diffusing the taste for chemistry and natural history, by making their relations and uses better known, conciliated the favour of government towards them; and from that moment every one interested himself in the progress of both sciences. Those persons who were best qualified in the kingdom, hastened to promote the revolution which was preparing. The sciences soon inscribed in their list of cultivators the beloved and respected names of La Rochefoucault, Ayen, Chaulnes, Lauraguais, Malesherve, &c.; and these men, distinguished by their birth, were honoured with a new species of glory, which is independent of chance or prejudice. They enriched chemistry with their discoveries, and associated their names with all the other literati who pursued the same career. They revived in the mind of the chemist that passion for glory, and that ardour for the public good, which continually excite new efforts. The man of ambition and intrigue no longer endeavoured to depress the modest and timid man of genius. The credit of men in place served as a defence and support against calumny and persecution. Recompenses were assigned to merit. Learned men were despatched into all parts of the world, to study the arts, and collect their productions. Men of the first merit were invited to instruct us with regard to our own proper riches; and establishments of chemistry which were made in the principal towns of the kingdom, diffused the taste for this science, and fixed among us those arts which we

might in vain have attempted to naturalize, if a firm basis had not been first laid. The professors established in the capital, and in the provinces, appeared to be placed between the academies and the people, to prepare the latter for those truths which flow from such respectable associations. We may consider them as a medium which refracts and modifies the rays of light that issue from those various luminous centres; and directs them towards the manufactories, to enlighten and improve their practice. Without these favours, without this consideration and these recompenses, could it have been expected that the most unassuming among philosophers would have exerted himself to promote the reputation of a people to whom he was unknown? Could a man so situated reasonably hope to succeed in carrying a discovery into effect? Is it probable that he should have possessed a sufficient fortune to work in the large way, and by this means alone to overcome the numberless prejudices which banish men of science from manufactories? The contemplative sciences demand of the sovereign repose and liberty only; but experimental sciences demand more, for they require assistance and encouragement. What indeed could be hoped in those barbarous ages, wherein the chemist scarcely durst avow the nature of the occupation which in secret constituted his greatest pleasure. The title of Chemist was almost a reproach: and the prejudice which confounded the professors of this science with such wretched projectors as are entitled only to pity, has probably kept back the revival of the arts for several centuries; for chemistry alone can afford them a proper basis. If the princes of past times had been friends of the arts, and jealous to acquire a pure and durable reputation; if they had been careful to honour the learned, to collect their valuable labours and to transmit to us without alteration the precious annals of human genius; we should have been dispensed from labouring among the rubbish of early times, to consult a few of those remains which have escaped the general wreck; and we should have been spared the regret of allowing, after many useless researches, that the masterpieces of antiquity which remain answer scarcely any other purpose than to give us an idea of that superiority

to which the earlier nations had arrived. Time, the sword, fire, and prejudice have devoured all; and our researches serve only to add to our regret for the losses which the world has sustained.

The science of chemistry possesses the glory, in our days, not only of having obtained the protection of government, but it may likewise boast of another equally elevated. This science has fixed the attention, and formed the occupation, of various men in whom the habit of a profound study of the accurate sciences had produced a necessity of admitting nothing but what is proved, and of attaching themselves only to such branches of knowledge as are susceptible of strict proofs. Messrs. De la Grange, Condorcet, Vander Monde, Monge, De la Place, Meusnier, Cousin, the most celebrated mathematicians of Europe, are all interested in the progress of this science, and most of them daily add to its progress by their discoveries.

So great a mass of instruction, and such ample encouragement, could not but effect a revolution in the science itself; and we are indebted to the combined efforts of all these learned men for the discovery of several metals, the creation of various useful arts, the knowledge of a number of advantageous processes, the working of several mines, the analysis of the gases, the decomposition of water, the theory of heat, the doctrine of combustion; and a mass of knowledge so absolute and so extended, respecting all the phenomena of art and of nature, that in a very short time chemistry has become a science entirely new. We might now say with much more truth what the celebrated Bacon affirmed of the chemistry of his time: "A new philosophy," says he, "has issued from the furnaces of the chemists, which has confounded all the reasonings of the ancients."

But while discoveries became infinitely multiplied in chemistry, the necessity of remedying the confusion which had so long prevailed, was soon seen, and indicated the want of a reform in the language of this science. There is so intimate a relation between words and facts, that the revolution which takes place in the principles of a science ought to be attended with a similar revolution in its language: and it is no more possible to preserve a vitious

nomenclature with a science which becomes enlightened, extended, and simplified, than to polish, civilize, and instruct uninformed man without making any change in his natural language. Every chemist who wrote on any subject was struck with the inaccuracy of the words in common use, and considered himself as authorized to introduce some change; insomuch that the chemical language became insensibly longer, more confused, and more unpleasant. Thus carbonic acid has been known, during the course of a few years, under the names of Fixed Air, Aerial Acid, Mephitic Acid, Cretaceous Acid, &c.; and our posterity may hereafter dispute whether these various denominations were not applied to different substances. The time was therefore come, in which it was necessary to reform the language of chemistry: the imperfections of the ancient nomenclature, and the discovery of many new substances, rendered this revolution indispensable. But it was necessary to defend this revolution from the caprice and fancy of a few individuals; it was necessary to establish this new language upon invariable principles: and the only means of insuring this purpose was doubtless that of erecting a tribunal in which chemists of acknowledged merit should discuss the words received without prejudice and without interest; in which the principles of a new nomenclature might be established and purified by the severest logic; and in which the language should be so well identified with the science, the word so well applied to the fact, that the knowledge of the one should lead to the knowledge of the other. This was executed in 1788 by Messrs. De Morveau, Lavoisier, Berthollet, and De Fourcroy.

In order to establish a system of nomenclature, bodies must be considered in two different points of view, and distributed into two classes; namely, the class of simple substances reputed to be elementary, and the class of combined substances.

1. The most natural and suitable denominations which can be assigned to simple substances, must be deduced from a principal and characteristic property of the substance intended to be expressed. They may likewise be distinguished by words which do not present any precise

idea to the mind. Most of the received names are established on this last principle, such as the names Sulphur, Phosphorus, which do not convey any signification in our language, and produce in our minds determinate ideas only, because usage has applied them to known substances. These words, rendered sacred by use, ought to be preserved in a new nomenclature; and no change ought to be made, excepting when it is proposed to rectify vitious denominations. In this case the authors of the new nomenclature have thought it proper to deduce the denomination from the principal characteristic property of the substance. Thus, pure air might have been called Vital Air, Fire Air, or Oxigenous Gas; because it is the basis of acids, and the aliment of respiration and combustion. But it appears to me that this principle has been in a small degree departed from when the name of Azotic Gas was given to the atmospherical mephitic—1. Because, none of the known gaseous substances excepting vital air being proper for respiration, the word Azote agrees with every one of them except one; and consequently this denomination is not founded upon an exclusive property, distinctive and characteristic of the gas itself. 2. This denomination being once introduced, the nitric acid ought to have been called Azotic Acid, and its combinations Azotates; because the acids are proposed to be denoted by the name which belongs to their radical. 3. If the denomination of Azotic Gas does not agree with this aëriiform substance, the name of Azote agrees still less with the concrete and fixed substance; for in this state all the gases are essentially azotes. It appears to me therefore that the denomination of Azotic Gas is not established according to the principles which have been adopted; and that the names given to the several substances of which this gas constitutes one of the elements, are equally removed from the principles of the nomenclature. In order to correct the nomenclature on this head, nothing more is necessary than to substitute to this word a denomination which is derived from the general system made use of; and I have presumed to propose that of Nitrogene Gas. In the first place, it is deduced from the characteristic and exclusive property of this gas, which forms the radical of the nitric acid. By this means we shall preserve to the combining

tions of this substance the received denominations, such as those of the Nitric Acid, Nitrates, Nitrites, &c. In this manner the word which is afforded by the principles adopted by the celebrated authors of the Nomenclature, causes every thing to return into the order proposed to be established.

2. The method made use of to ascertain the denominations suitable to compound substances, appears to me to be simple and accurate. It has been thought that the language of this part of science ought to present the analyses; that the words should be only the expression of facts; and that consequently the denomination applied by a chemist to any substance which has been analyzed, ought to render him acquainted with its constituent parts. By following this method, the nomenclature is as it were united, and identified with the science; and facts and words agree together. Two things are therefore united, which until this time appeared to have no mutual relation, the word, and the substance which it represented; and by this means the study of chemistry is simplified. But when we apply these incontestable principles to the various objects of chemistry, we ought to follow the analysis step by step, and on this ground alone establish general and individual denominations. We ought to observe that it is from this analytical method that the various denominations have been assigned, and that the methodical distributions of natural history have been at all times made. If man were to open his eyes for the first time upon the various beings which people or compose this globe, he would establish their relation upon the comparison of their most evident properties, and no doubt would found his first divisions upon the most sensible differences. The various modes of existence, or their several degrees of consistence, would form his first division; and he would arrange them under the heads of solid, liquid or aëriform bodies. A more profound examination, and a more connected analysis of the individuals, would soon convince him that the substances which certain general relations had induced him to unite in the same class, under a generic denomination, differed very essentially among each other, and that these differences necessarily required subdivision. Hence he would divide his solid bodies into stones, metals, ve-

getable substances, animal substances, &c.; his liquids would be divided into water, vital air, inflammable air, mephitic air, &c. When he proceeded to carry his researches on the nature of these substances still farther, he would perceive that most of the individuals were formed by the union of simple principles; and here it is that his applications of the system to be followed, in assigning a suitable denomination to each substance, would begin. To answer this purpose, the authors of the New Nomenclature have endeavoured to exhibit denominations which may point out the constituent principles. This admirable plan has been carried into execution as far as relates to substances which are not very complicated, such as the combinations of the principles with each other; the acids, earths, metals, alkalis, &c. And this part of the Nomenclature appears to me to leave nothing more to be desired. The explanation may be seen in the work published on this subject by the authors, and in the *Elementary Treatise of Chemistry* of Mr. Lavoisier. I shall therefore do nothing more in this place than present a sketch of the method I have followed; taking for example the combinations of acids, which form the most numerous class of compounds.

The first step consisted in comprehending under a general denomination the combination of an acid with any given basis; and in order to observe a more exact arrangement, and at the same time to assist the memory, one common termination has been given to all words which denote the combination of an acid. Hence the words Sulphates, Nitrates, Muriates, are used to denote combinations of the sulphuric, nitric, and muriatic acids. The kind of combination is denoted by adding to the generic word the name of the body which is combined with the acid; thus, the sulphate of pot-ash expresses the combination of the sulphuric acid with pot-ash.

The modifications of these same acids, dependant on the proportions of their constituent principles, form salts different from those we have just spoken of; and the authors of the New Nomenclature have expressed the modifications of the acids by the termination of the generic word. The difference in the acids arises almost always from the greater or less abundance of oxigene. In the

first case, the acid assumes the epithet of Oxigenated; hence the oxigenated muriatic acid, the oxigenated sulphuric acid, &c. In the second case, the termination of the word which denotes the acid, ends in *ous*; hence the sulphureous acid, the nitrous acid, &c. The combinations of these last form sulphites, nitrites, &c.; the combinations of the former compose oxigenated muriates, oxigenated sulphates, &c.

The combinations of the various bodies which compose this globe are not all as simple as those here mentioned; and it may be immediately perceived how long and troublesome the denominations would be, if attempts were made to bestow a single denomination which should denote the constituent principles of a body formed by the union of five or six principles. In this case, the preference has been given to the received appellation, and no other changes have been admitted but such as were necessary in order to substitute proper appellations instead of those which afforded notions contrary to the nature of the objects they were applied to.

I have adopted this Nomenclature in my lectures, and in my writings; I have not failed to perceive how very advantageous it is to the teacher, how much it relieves the memory, how greatly it tends to produce a taste for chemistry, and with what facility and precision the ideas and principles concerning the nature of bodies fix themselves in the minds of the auditors. But I have been careful to insert the technical terms used in the arts, or received in society, together with these new denominations. I am of opinion that, as it is impossible to change the language of the people, it is necessary to descend to them, and by that means render them partakers of our discoveries. We see, for example, that the artist is acquainted with the sulphuric acid by no other name than that of Oil of Vitriol, though the name of the Vitriolic Acid has been the language of chemists for a century past. We cannot hope to be more happy in this respect than our predecessors; and, so far from separating ourselves from the artist by a peculiar language, it is proper that we should multiply the occasions of bringing us together; so far from attempting to enslave him by our language, we ought rather to inspire his confidence by learning his terms. Let us prove

to the artist that our relations with him are more extended than he imagines; and let us by this intimacy establish mutual correspondence, and a concurrence of information, which cannot but redound to the advantage of the arts and of chemistry.

After having explained the principal objections which have retarded the improvement of chemistry, and the causes which in our time have accelerated its progress, we shall endeavour to point out the principal applications of this science; in which attempt, we think, we shall succeed best by casting a general retrospect over those arts and sciences which receive certain principles from it.

Most of the arts are indebted to accident for their discovery. They are in general neither the fruit of research, nor the result of combination, but all of them have a more or less evident relation to chemistry. This science therefore is capable of clearing up their first principles, reforming their abuses, simplifying their operations, and accelerating their progress.

Chemistry bears the same relation to most of the arts, as the mathematics have to the several parts of science which depend on their principles. It is possible, no doubt, that works of mechanism may be executed by one who is no mathematician; and so likewise it is possible to dye a beautiful scarlet without being a chemist: but the operations of the mechanic, and of the dyer, are not the less founded upon invariable principles, the knowledge of which would be of infinite utility to the artist.

We continually hear in manufactories of the caprices and uncertainty of operations; but it appears to me that this vague expression owes its birth to the ignorance of the workmen with regard to the true principles of their art. For nature itself does not act with determination and discernment, but obeys invariable laws; and the inanimate substance which we make use of in our manufactures, exhibits necessary effects, in which the will has no part, and consequently in which caprices cannot take place. Render yourselves better acquainted with the materials you work upon, we might say to the artists; study more intimately the principles of your art; and you will be able to foresee, to predict, and to calculate every effect. It is your ignorance alone which renders your operations a con-

usual series of trials, and a discouraging alternative of success and disappointment.

The public, which continually exclaims that experience is better than science, encourages and supports this ignorance on the part of the artist; and it will not be remote from our object to attempt to ascertain the true value of these terms. It is very true, for example, that a man who has had a very long experience may perform operations with exactness; but he will always be confined to the mere manipulation. I would compare such a man to a blind person who is acquainted with the road, and can pass along it with ease, and perhaps even with the confidence and assurance of a man who sees perfectly well; but is at the same time incapable of avoiding accidental obstacles, incapable of shortening his way or taking the most direct course, and incapable of laying down any rules which he can communicate to others. This is the state of the artist of mere experience; however long the duration of his practice may have been, as the simple performer of operations.

It may perhaps be replied, that artists have made very important discoveries in consequence of assiduous labour. This is indeed true, but the examples are very scarce; and we have no right to conclude, because we have seen men of genius without any mathematical theory execute wonderful works of mechanism, that the mathematics are not the basis, or that any one has a right to expect to become a great mechanic without a profound study of mathematical principles.

It appears to be generally admitted at present, that chemistry is the basis of the arts: but the artist will not derive from chemistry all the advantages he has a right to expect, until he has broken through that powerful barrier which suspicion, self-love, and prejudice have raised between the chemist and himself. Such philosophers as have attempted to pass this line, have frequently been repelled as dangerous innovators; and prejudice, which reigns despotically in manufactories, has not even permitted it to be thought that the processes were capable of improvement.

It is easy to shew the advantages which the arts might obtain from chemistry, by casting a retrospect over its applications to each of them in particular.

1. It appears, from the writings of Columella, that the ancients possessed a considerable extent of knowledge respecting agriculture, which was at that time considered as the first and noblest occupation of man. But when once the objects of luxury prevailed over those of necessity, the cultivation of the ground was left to the mere succession of practice, and this first of the arts became degraded by prejudices.

Agriculture is more intimately connected with chemistry than is usually supposed. It must be admitted that every man is capable of causing ground to bear corn; but what a considerable extent of knowledge is necessary to cause it to produce the greatest possible quantity! It is not enough, for this purpose, to divide, to cultivate and to manure any piece of ground: a mixture is likewise required of earthy principles so well assorted, that it may afford a proper nourishment; permit the roots to extend themselves to a distance, in order to draw up the nutritive juices; give the stem a fixed base; receive, retain, and afford upon occasion the aqueous principle, without which no vegetation can be performed. It is therefore essential to ascertain the nature of the earth, the avidity with which it seizes water, its force of retaining it, &c.; and these requisites point to studies which will afford principles not to be obtained by mere practice but slowly and imperfectly.

Every grain requires a peculiar earth. Barley vegetates freely among the dry remains of granite; wheat grows in calcareous earth, &c. And how can it be possible to naturalize foreign products, without a sufficient stock of knowledge to supply them with an earth similar to that which is natural to them?

The disorders of grain and forage, and the destruction of the insects which devour them, are objects of natural history and chemistry: and we have seen in our own times the essential art of drying and preserving grain, and all those details which are interesting in the preparation of bread, carried by the labours of a few chemists

to a degree of perfection which seemed difficult to have been attained.

The art of disposing stables in a proper manner, that of chusing water adapted for the drink of domestic animals, the economical processes for preparing and mixing their food, the uncommon talent of supplying a proper manure suited to the nature of soils, the knowledge necessary to prevent or to repair the effects of blights—all come within the province of chemistry; and without the assistance of this science our proceeding would be painful, slow, and uncertain.

We may at present insist upon the necessity of chemistry in the various branches of agriculture with so much the more reason, as government does not cease to encourage this first of arts by recompenses, distinctions, and establishments; and the views of the state are forwarded by the proposal of means to render this art flourishing. We see, with the greatest satisfaction, that, by a happy return of reflection, we begin to consider agriculture as the purest, the most fruitful, and the most natural source of our riches. Prejudices no longer tend to oppress the husbandman. Contempt and servitude are no longer the inheritance received for his incessant labours. The most useful and the most virtuous class of men is likewise that whose state is most minutely considered; and the cultivator of the ground in France is at last permitted to raise his hands in a state of freedom to heaven, in gratitude for this happy revolution.

2. The working of mines is likewise founded upon the principles of chemistry. This science alone points out and directs the series of operations to be made upon a metal, from the moment of its extraction from the earth until it comes to be used in the arts.

Before the chemical analysis was applied to the examination of stones, these substances were all denoted by superficial characters, such as colour, hardness, volume, weight, form, and the property of giving fire with the steel. All these circumstances had given rise to methods of division in which every other property was confounded; but the successive labours of Pott, Margraaff, Bergmann, Scheele, Bayen, Dietrich, Kirwan, Lavoisier, De Morveau, Aehard, Sage, Berthollet, Jerhard, Erhmann,

Fourcroy, Mongez, Klaproth, Crell, Pelletier, De la Metherie, &c. by instructing us concerning the constituent principles of every known stone, have placed these substances in their proper situations, and have carried this part of chemistry to the same degree of precision as that which we before possessed respecting the neutral salts.

The natural history of the mineral kingdom, unassisted by chemistry, is a language composed of a few words, the knowledge of which has acquired the name of Mineralogist to many persons. The words Calcareous Stone, Granite, Spar, Schorle, Feld Spar, Schistus, Mica, &c. alone compose the dictionary of several amateurs of natural history ; but the disposition of these substances in the bowels of the earth, their respective position in the composition of the globe, their formation and successive decompositions, their uses in the arts, and the knowledge of their constituent principles, form a science which can be well known and investigated by the chemist only.

It is necessary therefore that mineralogy should be enlightened by the study of chemistry ; and we may observe that, since these two sciences have been united, the labour of working mines has been simplified, metallic ores have been wrought with more intelligence, several new metallic substances have been discovered, individuals have opened mines in the provinces ; and we have become familiar with a species of industry which seemed foreign, and almost incompatible with our soil and our habits. Steel and the other metals have received in our manufactories that degree of perfection which had till lately excited our admiration, and humiliated our self-love. The superb manufacture of Creusot has no equal in Europe. Most of our works are supported by pit-coal ; and this new combustible substance is so much the more valuable, as it affords us time to repair our exhausted woods, and as it is found almost every where in those barren soils which repel the ploughshare, and prohibit every other kind of industry. The eternal gratitude of this country is therefore due to Messrs. Jars, Dietrich, Duhamel, Monet, Gensanne, &c. who first brought us acquainted with these true riches. The taste for mineralogy, which has diffused itself within our remembrance, has not a little contributed to produce this

revolution; and it is in a great measure owing to those collections of natural history, against which some persons have so much exclaimed, that we are indebted for this general taste. Our collections have the same relation to natural history, as books bear to literature and the sciences. The collection frequently is nothing more than an object of luxury to the proprietor; but in this very case it is a resource always open to the man who is desirous of beholding, and instructing himself. It is an exemplar of the works of nature, which may be consulted every moment; and the chemist who runs over all these productions, and subjects them to analyses to ascertain their constituent principles, forms the precious chain which unites nature and art.

3. While the chemist attends to the nature of bodies, and endeavours to ascertain their constituent principles, the natural philosopher studies their external characters, and as it were their physiognomy. The object of the chemist ought therefore to be united to that of the philosopher, in order to acquire a complete idea of a body. What in fact shall we call air or fire, without the instruction of the chemist? Fluids more or less compressible, ponderous, and elastic. What are the particulars of information which natural philosophy affords us concerning the nature of solids? It teaches us to distinguish them from each other, to calculate their weight, to determine their figure, to ascertain their uses, &c.

If we cast our attention upon the numerous particulars which chemistry has lately taught us respecting air, water, and fire, we shall perceive how much the connexion of these two sciences has been strengthened. Before this revolution, natural philosophy was reduced to the simple display of machines; and this coquetry, by giving it a transient glare, would have impeded its progress, if chemistry had not restored it to its true destination. The celebrated chancellor Bacon compared the natural magic, or experimental philosophy, of his time, to a magazine in which a few rich and valuable moveables were found among a heap of toys. The curious, says he, is exhibited instead of the useful. What more is required to draw the attention of great men, and to

form that transient fashion of the day which ends in contempt?

The natural philosophy of our days no longer deserves the reproaches of this celebrated philosopher. It is a science founded on two bases equally solid. On the one part, it depends on mathematical science for its principles; and on the other, it rests upon chemistry. The natural philosopher will attend equally to both sciences.

The study of chemistry, in certain departments, is so intimately connected with that of natural philosophy, that they are inseparable; as, for example, in researches concerning air, water, fire, &c. These sciences very advantageously assist each other in other respects; and while the chemist clears minerals from the foreign bodies which are combined with them, the philosopher supplies the mechanical apparatus necessary for exploring them. Chemistry is inseparable from natural philosophy even in such parts as appear the most independent of it; such, for example, as optics, where the natural philosopher can make no progress but in proportion as the chemist shall bring his glass to perfection.

The connexion between these two sciences is so intimate, that it is difficult to draw a line of distinction between them. If we confine natural philosophy to inquiries relative to the external properties of bodies, we shall afford no other object but the mere outside of things. If we restrain the chemist to the mere analysis, he will at most arrive at the knowledge of the constituent principles of bodies, and will be ignorant of their functions. These distinctions in a science which has but one common purpose, namely, the complete knowledge of bodies, cannot longer exist; and it appears to me that we ought absolutely to reject them in all objects which can only be well examined by the union of natural philosophy and chemistry.

At the period of the revival of letters, it was of advantage to separate the learned, as it were, upon the road to truth; and to multiply the workshops, if I may use the expression to hasten the clearing away. But at present, when the various points are re-united, and the connexion between the whole is seen, these separations, these divi-

sions, ought to be effaced; and we may flatter ourselves that, by uniting our efforts, we may make a rapid progress in the study of nature. The meteors, and all the phenomena of which the atmosphere is the grand theatre, can be known only by this re-union. The decomposition of water in the bowels of the earth, and its formation in the fluid which surrounds us, cannot but give rise to the most happy and the most sublime applications.

4. The connexion between chemistry and pharmaey is so intimate, that these two sciences have long been considered as one and the same; and chemistry, for a long time, was cultivated only by physicians and apothecaries. It must be allowed that, though the chemistry of the present day, is very different from pharmaey, which is only an application of the general principles of this science, these applications are so numerous, the class of persons who cultivate pharmacy is in general so well informed, that it is not at all to be wondered at, that most apothecaries should endeavour to enlighten their profession by a serious study of chemistry, and by the happiest agreement unite the knowledge of both parts of science.

The abuses which, at the beginning of the present century, were made of the applications of chemistry to medicine, have caused the natural and intimate relations of this science with the art of healing to be mistaken. It would have been more prudent, no doubt, to have rectified its applications; but unfortunately we have too much ground to reproach physicians for going to extremes. They have, without restriction, banished that which they before received without examination; and we have seen them successively deprive their art of all the assistance it might obtain from the auxiliary sciences.

In order to direct with propriety the applications of chemistry to the human body, proper views must be adopted relating to the animal economy, together with accurate notions of chemistry itself. The results of the laboratory must be considered as subordinate to physiological observations. We should endeavour to enlighten the one by the other, and to admit no truth as established which is contradicted by any of these means of conviction. It is in consequence of a departure from these principles that the human body has been considered as a lifeless and passive

substance ; and that the strict principles observed in the operations of the laboratory have been applied to this living system.

In the mineral kingdom, every thing is subjected to the invariable laws of the affinities. No internal principle modifies the action of natural agents ; and hence it arises that we are capable of foretelling, producing or modifying the effects.

In the vegetable kingdom, the action of external agents is equally evident ; but the internal organization modifies their effects, and the principal functions of vegetables arise from the combined action of external and internal causes. It was no doubt for this reason that the Creator disposed the principal organs of vegetation upon the surface of the plant, in order that the various functions might at the same time receive the impressions of external agents, and that of the internal principle of the organization.

In animals the functions are much less dependant on external causes ; and nature has concealed the principal organs in the internal parts of their bodies, as if to withdraw them from the influence of foreign powers. But the more the functions of an individual are connected with its organization, the less is the empire of chemistry over them ; and it becomes us to be cautious in the application of this science to all the phenomena which depend essentially upon the principles of life.

We must not, however, consider chemistry as foreign to the study and practice of medicine. This science alone can teach us the difficulty and art of combining remedies. This alone can teach us to apply them with prudence and firmness. Without the assistance of this science, the practitioner would scarcely venture to apply those powerful remedies from which the chemical physician knows the means of deriving such great advantage. Chemistry alone in all probability, is capable of affording means of combating epidemic disorders, which in most cases are caused by an alteration in the air, the water, or our food. It will be only in consequence of analysis that the true remedy can be found against those stony concretions which form the matter of the gout, the stone, the rheumatism, &c. ; and the valuable particulars of infor-

mation which we now possess respecting respiration, and the nature of the principal humours of the human body, are likewise among the benefits arising from this science.

5. Chemistry is not only of advantage to agriculture, physic, mineralogy, and medicine, but its phenomena are interesting to all the orders of men: the applications of this science are so numerous, that there are few circumstances of life in which the chemist does not enjoy the pleasure of seeing its principles exemplified. Most of those facts which habit has led us to view with indifference are interesting phenomena in the eyes of the chemist. Every thing instructs and amuses him; nothing is indifferent to him, because nothing is foreign to his pursuits; and nature, no less beautiful in her most minute details than sublime in the disposition of her general laws, appears to display the whole of her magnificence only to the eyes of the chemical philosopher.

We might easily form an idea of this science, if it were possible to exhibit in this place even a sketch of its principal applications. We should see, for example, that chemistry affords us all the metals of which the uses are so extensive; that chemistry affords us the means of employing the parts of animals and of plants for our ornament; that our luxuries, and our subsistence, are by this science established as a tax upon all created beings; and that by this power we are taught to subject nature to our wants, our taste, and even to our caprices. Fire, that free independent element, has been collected and governed by the industry of the chemist; and this agent, destined to penetrate, to enliven, and to animate the whole of nature, has in his hands become the agent of death, and the prime minister of destruction. The chemists who in our time have taught us to insulate that pure air which alone is proper for combustion, have placed in our hands, as it were, the very essence of fire; and this element, whose effects were so terrible, becomes the agent of still more terrible consequences. The atmosphere, which was formerly considered as a mass of homogeneous fluid, is now found to be a true chaos, from which analysis has obtained principles so much the more interesting to be known, as nature has made them the principal agents of her operations. We may consider this mass of fluid in

which we live as a vast laboratory, in which the meteors are prepared, in which all the seeds of life and of death are developed, from which nature takes the elements of the composition of bodies, and to which their subsequent decomposition returns the same principles which were before extracted.

Chemistry, by informing us of the nature and principles of bodies, instructs us perfectly concerning our relation to the objects around us. This science teaches us, as it were, to live with them; and impresses a true life upon them, since by this means each body has its name, its character, its uses, and its influence, in the harmony and arrangement of this universe.

The chemist, in the midst of those numerous beings which the common race of men accuse nature of having vainly placed upon our globe, enjoys the prospect as it were in the centre of a society, all whose members are connected together by intimate relations, and concur to promote the general good. In his sight every thing is animated, every being performs a part on this vast theatre; and the chemist who participates in these interesting scenes, is repaid with usury for his first exertions to discover the relations existing between them.

We may even consider this commerce, or mutual relation between the chemist and nature, as very proper to soften the manners, and to impress on the character that freedom and firmness of principle so valuable in society. In the study of natural history, no cause ever presents itself to complain of inconstancy or treachery. An attachment is easily contracted for objects which afford enjoyment only; and these connexions are as pure as their object, as durable as nature, and stronger in proportion to the exertions which have been required to establish them.

From all these considerations, there is no science which more eminently deserves to enter into the plan of a good education than chemistry. We may even affirm that the study of this science is almost indispensably necessary to prevent us from being strangers in the midst of the beings and phenomena which surround us. It is true indeed that the habit of beholding the objects of nature may produce a knowledge of some of their principal properties. We may even in this way arrive at the theory of some of the

phenomena. But nothing is more proper to check the pretensions of young persons who are elevated by such imperfect acquisitions, than to shew them the vast field of which they are ignorant. The profoundest sentiment of their ignorance will be seconded by the natural desire of acquiring new knowledge. The wonderful properties of the objects presented to them will engage their attention. The interesting nature of the phenomena will tend to excite their curiosity. Accuracy of experiment, and strictness of result, will form their reasoning powers, and render them severe in their judgment. By studying the properties of all the bodies which surround him, the young scholar learns to know their relation with himself; and by successively attending to all objects, he extends the circle of his enjoyment by new conquests. He becomes a partaker in the privileges of the Creator, by uniting and disuniting, by compounding and destroying. We might even affirm that the Author of nature, reserving to himself alone the knowledge of his general laws, has placed man between himself and matter, that it may receive these laws from his hands, and that he may apply them with proper modifications and restrictions. In this view, therefore, we may consider man as greatly superior to the other beings which compose this living system. They all follow a monotonous and invariable process; receive the laws, and submit to effects without modification. Man alone possesses the rare advantage of knowing a part of these laws, of preparing events, of predicting results, of producing effects at pleasure, of removing whatever is noxious, of appropriating whatever is beneficial, of composing substances which nature herself never forms; and, in this last point of view, himself a Creator, he appears to partake with the Supreme Being in the most eminent of his prerogatives.

ELEMENTS OF CHEMISTRY.

PART THE FIRST.

Concerning the Chemical Principles.

INTRODUCTION.

Definition of Chemistry ; its Object and Means—Description of a Laboratory, and the principal Instruments employed in chemical Operations, with a Definition of those Operations.

CHEMISTRY is a science, the object of which is to ascertain the nature and properties of bodies.

The methods used to obtain this knowledge are reducible to two; analysis and synthesis.

The principal operations of chemistry are performed in a place called a Laboratory.

A laboratory ought to be extensive and well aired, in order to prevent dangerous vapours from remaining, which are produced in some operations, or which may escape by any unforeseen accident. It ought to be dry, because otherwise iron vessels would rust, and most of the chemical products would be liable to change. But the principal excellence of a laboratory consists in its being furnished with all those instruments which may be employed in the study of the nature of bodies, and in inquiries respecting their properties.

Among these instruments there are some which are of general use, and applicable to most operations; and there are others which serve only for peculiar uses. This division immediately points out that, at the present instant, we can only treat of the former, and that we must describe the others on such occasions as will render it necessary to treat of their uses.

The chemical instruments most frequently employed are those which present themselves first to view upon entering a laboratory; namely, the furnaces.*

These furnaces consist of earthen vessels appropriated to the various operations performed upon bodies by means of fire.

A proper mixture of sand and clay is commonly the material of which these vessels are formed. It is difficult, and even impossible, to prescribe and determine, according to any invariable method, the proportions of these constituent parts; because they must be varied according to the nature of the earth made use of. Habit and experience alone can furnish us with principles on this subject.

The several methods of applying fire to substances under examination, has occasioned the construction of furnaces in different forms, which we shall at present reduce to the three following.

I. The evaporatory furnace.—This furnace has received its name from its use. It is used to reduce liquid substances into vapour by means of heat, in order to separate the more fixed principles from those which are more ponderous; and were mixed, suspended, compounded, or dissolved in the fluid.

The fire-place is covered by the evaporatory vessel. Two or three grooves, channels, or depressions are made in the sides of the furnace near its upper edge, to facilitate the drawing of the fire.

The vessel which contains the substance to be evaporated, is called the evaporatory vessel.

These vessels are formed of earth, glass or metal. Vessels of unglazed earth are too porous, insomuch that liquids filtrate through their texture. Those of porcelain biscuit are likewise penetrable by liquids strongly heated, and suffer gaseous or aëriiform substances to escape. The

* The only furnaces to be procured in the United States, are made of thick sheet iron, and they are very durable and cheap. The one, plate 2, fig. 1. is ten inches high from the grate, and ten inches in diameter. Two round holes, two and a half inches wide, are made in the middle of the sides, in order to submit many substances to a high degree of heat, in order to transmit liquids or gases over them, in an earthen, copper or iron tube. A common chafing-dish, is a very useful furnace, in a great many chemical operations. *Am. Ed.*

Beautiful experiments of Mr. D'Arcet upon the combustion and destruction of the diamond, in balls of porcelain, are well known, and tend to illustrate this subject. I have confirmed these results by experiments in the large way, upon the distillation of aqua-fortis, which loses as well in quality as quantity when the process is carried on in vessels of porcelain clay.

Glazed earthen vessels cannot be used when the glass consists of the calces of lead or copper; because those metallic matters are attacked by acids, fats, oils, &c. Neither can earthen vessels be used which are covered with enamel, because this kind of opaque glass is almost always full of small cracks, through which the liquid would introduce itself into the body of the vessel.

Earthen vessels cannot therefore be used, excepting in operations of little delicacy, in which precision and accuracy are not indispensably required.

Evaporatory vessels of glass are in general to be preferred. Those which resist the fire better than any others, are prepared in the laboratory, by cutting a sphere of glass or a receiver into two equal parts with a red-hot iron. The capsules which are made in the glass-house are thickest at the bottom, and consequently are more liable to break at that part when exposed to the fire.

Evaporatory vessels of metal are used in manufactories. Copper is most commonly employed, because it not only possesses the property of resisting fire, but has a considerable degree of solidity, together with the facility of being wrought. Alembics are made of this metal, for the distillation of vinous spirits, and aromatic substances; as are also caldrons or pots for the crystallization of certain salts, and for several dying processes, &c. Lead is likewise of considerable use, and is made choice of whenever operations are to be performed upon substances which contain the sulphuric acid, such as the sulphates of alumine and of iron; and for the concentration and rectification of the oil of vitriol. Tin vessels are also employed in some operations: the scarlet bath affords a more beautiful colour in boilers of this metal than in those of any other. Capitals of tin have already begun to be substituted in the room of those of copper, in the construction of alembics; and by this means the several products of distillation are ex-

empted from every suspicion of that dangerous metal. Boilers of iron are likewise used for certain coarse operations; as, for example, in the concentration of the lixiviums of common salt, of nitre, &c.

Evaporatory vessels of gold, of silver, or of platina, are to be preferred in some delicate operations; but the price and scarcity of these vessels do not permit them to be used, especially in the large way.

Moreover it is from the nature of the substance to be evaporated, that we must determine the choice of the vessel most suitable to any operation. There is no particular kind of vessel which can be adapted exclusively on all occasions. It may only be observed, that glass presents the greatest number of advantages, because it is composed of a substance the least attacked, the least soluble, and the least destructible by chemical agents.

Evaporatory vessels are known by the name of capsules, cucurbits, &c. according to their several forms.

These vessels ought in general to be very wide and shallow, in order that the distillation and evaporation may be speedy and economical. It is necessary, 1. That the evaporatory vessel be not narrow at its upper part. 2. That the heat be applied to the liquid in all parts, and equally. 3. That the column or mass of the liquid should have little depth, and a large surface of evaporation. It is upon these principles that I have constructed, in Languedoc, boilers proper for distilling brandy, which save eleventwelfths of the time, and four-fifths of the combustibles.

Evaporation may be performed in three manners. 1. By a naked fire. 2. By the sand bath. 3. By the water bath.

Evaporation is made by a naked fire, when there is no substance interposed between the fire and the vessel which contains the liquid intended to be evaporated; as, for example, when water is boiled in a pot.

Evaporation is performed by the sand bath, when a vessel filled with sand is interposed between the fire and the evaporatory vessel. The heat is in this case communicated more slowly and gradually; and the vessels, which would otherwise have been broken by the immediate application of the heat, are enabled to resist its force. The heat is at the same time more equally kept up; the refri-

geration is more gradual; and the operations are performed with a greater degree of order, precision, and facility.

If, instead of employing a vessel filled with sand, we use a vessel of water, and the evaporatory vessel be plunged in the liquid, the evaporation is said to be made on the water bath: in this case the substance to be evaporated is only heated by communication from the water. This form or method of evaporating is employed when certain principles of great volatility, such as alcohol, or the aromatic principles of plants, are to be extracted or distilled. It possesses the advantage of affording products which are not changed by the fire, because the heat is transmitted to them by the intervention of a liquid: it is this circumstance which renders the process valuable for the extraction of volatile oils, perfumes, ethereal liquids, &c. It possesses the advantage of affording a heat nearly equal, because the degree of ebullition is a term nearly constant; and this standard heat may be graduated or varied at pleasure, by adding salts to the liquid of the water bath, because this single circumstance renders the ebullition more or less quick and easy. The same effect may likewise be produced by restraining the evaporation; for in this case the liquid may assume a degree of heat much more considerable, as is seen in the digester of Papin, steam engines, eolipiles, and the boilers for striking the red tinge in cotton.

Sublimation differs from evaporation, because the substance to be raised is solid. The vessels used in this operation are known by the name of sublimatory vessels. These are commonly globes terminating in a long neck: they are then called matrasses.*

In order to sublime any substance, a part of the ball of the matrass is surrounded with sand. The matter which is volatilized by the heat, rises, and is condensed against the coldest part of the vessel; where it forms a stratum or cake, that may be taken out by breaking the vessel itself. In this manner it is that sal ammoniac, cor-

* Vessels for subliming should be of a circular form, shaped flat like a turnip, and have a projecting neck, two or three inches in length, with an aperture in it, about an inch in diameter. Vide plate ii. figure 3. *Am. Ed.*

rosive sublimate, and other similar products, are formed for the purposes of commerce.

Sublimation is usually performed either for the purpose of purifying certain substances, and disengaging them from extraneous matters; or else to reduce into vapour, and combine under that form, principles which would have united with great difficulty if they had not been brought to that state of extreme division.

II. The reverberatory furnace.—The name of the reverberatory furnace has been given to that construction which is appropriated to distillation.

This furnace is composed of four parts. 1. The ash-hole intended for the free passage of the air, and to receive the ashes or residue of the combustion. 2. The fire-place, separated from the ash-hole by the grate, and in which the combustible matter is contained. 3. A portion of a cylinder, which is called the laboratory, because it is this part which receives the retorts employed in the operations or distillations. 4. These three pieces are covered with a dome, or portion of a sphere, pierced near its upper part by an aperture, which affords a free passage to the current of air, and forms a chimney. The most usual form of the reverberatory furnace is that of a cylinder terminated by a hemisphere, out of which arises a chimney of a greater or less length, to produce a suitable degree of aspiration.

In order that a reverberatory furnace may be well proportioned, it is necessary, 1. That the ash-hole should be large, to admit the air fresh and unaltered. 2. That the fire-place and laboratory together should have the form of a true ellipsis, whose two foci should be occupied by the fire and the retort. In this case all the heat, whether direct or reflected, will strike the retort.

The reverberatory furnace is used for distillation. Distillation is that process by which the force of fire is applied to disunite and separate the several principles of bodies, according to the laws of their volatility, and their several affinities.

Distilling vessels are known by the name of retorts.

Retorts are formed of glass, of stone-ware, of porcelain, or of metal; these substances being respectively

used, according to the nature of the bodies intended to be exposed to distillation.

Whatever be the nature of the material, the forms of retorts are the same. This figure resembles an egg, terminating in a beak or tube, which diminishes insensibly in diameter, and is slightly inclined or bended.

The oval portion of the retort, which is called its belly, is placed in the laboratory of the furnace, and is supported upon two bars of iron, which separate the laboratory from the fire-place; while the beak or neck of the retort issues out of the furnace through a circular aperture formed in the edges of the dome and of the laboratory.*

A vessel intended to receive the product of the distillation is fitted to the neck of the retort. This vessel is called the recipient, or receiver.

The receiver is commonly a sphere with two apertures: the one of considerable magnitude, to receive the neck of the retort; the other smaller, to afford vent for the vapours. This part is called the tubulure of the receiver; whence the terms tubulated receiver, or receiver not tubulated, &c.

Though the reverberatory furnace be particularly adapted to distillation, this operation may be performed on the sand-bath; and here, as in other cases, it depends singly on the intelligence of the artist to vary his apparatus according to the necessity of circumstances, and the nature of the substances upon which he operates.

The construction of these furnaces may likewise be varied; and the chemist will find it necessary to learn the art of availing himself of every apparatus he possesses, to carry his operations into execution: for if he should persuade himself that it is impossible to proceed in chemical research, excepting in a laboratory provided with all suitable vessels; he may let the moment pass in which a discovery might be made, but which may not again return. And it may truly be said, that he who treads servilely in the paths of others who have gone before him, will never attain to the discovery of new truths.

* The neck of a glass retort, should be two feet in length, in order to guard the receiver, from the action of heat. *Am. Ed.*

III. The forge furnace.—The forge furnace is that in which the current of air is determined by bellows. The ash-hole, the fire-place, and the laboratory are here all united together, and this assemblage forms only a portion of a cylinder, pierced near the lower angle by a small hole, into which the tube of the bellows enters. This part is sometimes covered with a hemisphere or dome, to concentrate the heat with greater efficacy, and to reflect it upon the bodies exposed to it. The forge furnace is employed in the fusion and calcination of metals, and generally for all the operations which are performed in crucibles.

By crucibles we understand vessels of earth or metal, which are almost always of the form of an inverted cone. A crucible ought to support the strongest heat without melting: it ought to resist the attacks of all such agents as are exposed to heat in vessels of this kind. Those crucibles which possess the greatest degree of perfection, are made in Hesse or in Holland. I have made very good ones by a mixture of raw and unbaked clay from Salavas in the Vivarais.

Our laboratories have been provided with crucibles of platina, which unite the most excellent properties. They are nearly infusible, and at the same time indestructible by the fire.*

The several earthen vessels concerning which we have here treated, may be fabricated by the hand, or wrought in the lathe. The first proceeding renders them more solid, the clay is better united, and it is the only method used in glass manufactories; but the second method is more expeditious.

The agent of such decompositions as are effected by means of furnaces, is fire. It is afforded by the combustion of wood, pit-coal, or charcoal.

Wood is only employed in certain large works; and we prefer charcoal in our laboratories, because it does not smoke, has no bad smell, and burns better in small masses than other combustibles. We choose that which is the most sonorous, the driest, and the least porous.

* Crucibles of cast iron, which are extremely useful, and convenient, may be obtained at any of the iron works in the United States. *Am. Ed.*

But in the several operations we are about to describe, it is necessary to defend the retorts from the immediate action of the fire ; and also to coerce and restrain the expansible vapours, which are very elastic, and frequently corrosive. It is to answer these purposes that various lutes are employed.

1. A glass retort exposed to the action of the fire would infallibly break, if the operator were not to have recourse to the prudent precaution of coating it with earth.*

I have found it advantageous for the coating of retorts, to use a mixture of fat earth and fresh horse dung : for this purpose, the fat earth is suffered to rot for some hours in water ; and when it is moistened, and properly softened, it must be kneaded with the horse dung, and formed into a soft paste, which is to be applied and spread with the hand upon every part of the retort intended to be exposed to the action of the fire. The horse dung combines several advantages. 1. It contains a serous fluid, which hardens by heat, and strongly connects all the parts together : when this juice has been altered by fermentation or age, the dung does not possess the same virtue. 2. The filaments or stalks of hay, which are so easily distinguished in horse dung, unite all the parts of the lute together.

Retorts luted in this manner resist the impression of the fire very well ; and the adhesion of the lute to the retort is such, that even should the retort fly during the operation, the distillation may be still carried on, as I have daily experience in works in the large way,

2. When it is required to coerce or oppose the escape of the vapours which are disengaged during any operation it is no doubt sufficient if the joinings of the vessels be covered with paper glewed on, or with slips of bladder moistened with the lute of lime and white of egg, provided the vapours be neither dangerous nor corrosive ; but, when the vapours are corrosive, it is necessary to use the fat lute to retain them.

* It is very rarely necessary to coat a glass retort, in the manner recommended by the author. The flame of an Argand lamp, may be at any time applied to its bottom, without any danger of its cracking. *Am. Ed.*

Fat lute is made with boiled linseed oil mixed and well incorporated with sifted clay. Nut oil, kneaded with the same clay, forms a lute possessing the same properties. It is easily extended in the hand, and is used for defending the joinings of vessels, upon which it is afterwards secured by strips of linen, dipped in the lute of lime and white of egg. Before the application of heat in any distillation, it is necessary first to suffer the lutes to dry. Without this precaution, the vapours would rise and escape; or otherwise they would combine with the water which moistens the lutes, and would corrode and destroy the bladder, the skin, the paper, and in a word every substance used to secure them in their places. The lute of lime and white of egg dries very speedily, and must be used the moment it is made. This lute, likewise, opposes the greatest resistance to the escape of the vapours, and adheres the most intimately to the glass. It is made by mixing a small quantity of finely-powdered quick-lime with white of egg, and afterwards beating up the mixture to facilitate the combination. It must then be instantly applied on pieces of old linen, to be wrapped round the places of joining.*

In the large works, where it is not possible to attend to all these minute details, the joinings of the retort and receiver are luted together with the same lute which is used to coat the retorts. A covering of the thickness of a few lines is sufficient to prevent the vapours of the marine or nitrous acid from escaping.

As in certain operations a disengagement takes place of so prodigious a quantity of vapours, that it is dangerous to confine them; and as, on the other hand, the suffering them to escape would occasion a considerable loss in the product; an apparatus has been contrived of great ingenuity and simplicity to moderate the issue, and to retain without risk such vapours as would otherwise escape. This apparatus is known by the name of its author, Mr. Woulfe, a famous English chemist. His most excellent process consists in adapting the extremity of a recurved tube to the tubulure of the receiver; the other

* A lute made of flour and water, and spread upon paper, and applied where the retort joins the receiver, is one of the best, that has ever been used. *Am. Ed.*

end of which is plunged into water, in a bottle half filled, and properly placed for that purpose. From the empty part of this bottle issues a second tube, which is in like manner plunged in the water of a second bottle. A number of other bottles may be added, observing the same precautions; with the attention, nevertheless, to leave the last open, to give a free escape to the vapours which are not coercible: and, when the apparatus is thus disposed, all the joinings are to be luted. It will easily be imagined that the vapours which escape from the retort are obliged to pass through the tube adapted to the tubulure of the receiver, and consequently must pass through the water of the first bottle: they therefore suffer a first resistance, which partly condenses them. But as almost all vapours are more or less miscible and soluble in water, a calculation is previously made of the quantity of water necessary to absorb the vapours which are disengaged from the mixture in the retort; and care is taken to distribute this proper quantity of water in the bottles of the apparatus.

By this means we obtain the purest and most concentrated products; because the water, which is always in the receiver, and is the vehicle of these substances, becomes saturated with them. There is, perhaps, no other method of obtaining products always of an equal energy, and comparable in their effects; a circumstance of the greatest importance in the operations of the arts, as well as in philosophical experiments.

I have applied this apparatus to works in the large way; and I use it to extract the common muriatic acid, the oxygenated muriatic acid, ammoniac or volatile alkali, &c.

As it would very often happen, in this apparatus, that the pressure of the external air would cause the water of the outer vessels to pass into the receiver, in consequence of the simple refrigeration of the retort; this inconvenience has been obviated, by inserting a straight tube into the necks of the first and the second bottles, to such a depth, that its lower end is plunged into the water, while its other end rises several inches above the neck of the bottle. It may easily be conceived, as a consequence of this disposition, that when the dilated vapours of the receiver and retort are condensed by cooling, the external air will rush

through these tubes to establish the equilibrium; and water cannot pass from the one to the other.

Before the invention of this apparatus, it was usual to drill a hole in the receiver, which was kept closed, and only opened from time to time for the escape of the vapours. This method was inconvenient in many respects. In the first place, and principally, because, in spite of all precautions, it was attended with the risk of an explosion every moment, by the irregular disengagement of the vapours, and the impossibility of calculating the quantity produced in a given time. A second inconvenience was, that the vapours which thus escaped occasioned a considerable loss in the product, and even weakened the remainder; because this volatile principle consisted of the strongest part. A third inconvenience was, that the vapours which did escape incommoded the artist to such a degree, that it was impossible to perform most of the operations of chemistry in the course of a lecture, where a considerable number of auditors were present.

Thus it is that the apparatus of Woulfe unites a number of advantages: on the one hand, economy in the processes, and superiority in the product; on the other hand, safety for the chemist and his assistants: and in every point of view the author is entitled to the best acknowledgments of chemists, who were too often so much affected with these unwholesome exhalations, that their health was either totally destroyed, or they fell absolute victims to their zeal for the promotion of science.

It is necessary that a laboratory should be provided with balances of the utmost accuracy; for the chemist, who very frequently operates only upon small quantities, ought to be able by the strictness of his operations, and the accuracy of his apparatus, to produce results comparable with those of works in the large way. It frequently happens that the simple assay of a specimen of an ore determines the opening of a mine: and it scarcely need be pointed out, of how great consequence it is to remove every cause of error from the operations of chemistry; since the slightest error in the works of the laboratory may be attended with the most unhappy consequences, when the application of the principles is made to works in the large way.

We shall treat of other vessels and of the chemical apparatus, in proportion as we shall have occasion to make use of them; for it appears to us that, by thus connecting the description with their use, we shall succeed better in rendering them intelligible to the reader, at the same time that his memory will be less fatigued.*

* *Explanation of the Plates.*—Plate I.

Fig. 1. A is a stand, made of tin, thirteen inches high, consisting of a flat bottom, from which proceeds four upright pieces of the same metal, one inch broad, which are riveted to the top, in which there is a round aperture, three inches in diameter, to receive the bottom of a retort or oil-flask. B is one of Argand's lamps; C a retort, luted to a receiver D, which is supported by a frame of wood E. The case F, which is placed over the retort, to confine the heat of the lamp, is formed of two pieces of tin which include a column of atmospheric air one inch thick between them. It is ten inches in height; the opening in the side is three and a half inches, and the internal diameter seven inches.

Fig. 2. A is a cylindrical vessel of tin, thirteen inches high, and twenty-one in circumference, open at *a*, so as to admit a lamp, with a round aperture in the top, three inches in diameter. B is a circular case, four inches high, formed of two pieces of the same metal, which include a column of atmospheric air, one inch thick, at the top and on the sides. The lower part has an opening five inches in diameter, and in the middle of the upper part, there is an aperture to receive the neck of an oil flask. C is a flask from which proceeds the tube D, which enters the bottle E.

In using this apparatus, the flask, containing the subject of the operation, must be placed on the cylindrical body A. The case B is then to be put over the flask, and the tube D, which enters a perforated cork, luted to it with a strip of paper, covered with a paste made of flour and water. The atmospheric air which the case B contains, is a bad conductor of heat; hence upon applying an Argand lamp to the bottom of the flask, the heat is accumulated round its sides, and thus prevented from flying off into the air.

Fig. 3. A is the cylindrical vessel of tin, E the case containing the atmospheric air, and F an oil flask, on the neck of which, the head of an alembic B, made of tin or copper, seven inches high, is placed. C, the neck of this vessel, thirteen inches long, enters an oil-flask D.

To use this apparatus, the flask must be placed on the top of the cylindrical body A. The vessel containing the atmospheric air, is then to be placed over the flask, and the head of the alembic fixed to its neck. G, the part over the top of the head of the alembic, must be filled with cold water.

This economical apparatus may be used;

First. In obtaining gases from certain substances, which require the application of heat; as oxygenous air, from manganese or red lead and the sulphuric acid; or ammoniacal gas, from lime and sal

SECTION I.

Concerning the General Law which tends to bring the Particles of Bodies together, and to maintain them in a State of Mixture or Combination.

THE Supreme Being has given a force of mutual attraction to the particles of matter; a principle which is alone sufficient to produce that arrangement which the bodies of this universe present to our observation. As a

ammoniac; or oxymuriatic gas from the manganese and the marine acid, &c.

Secondly. In making ammoniac, and the liquid and concrete carbonate of ammoniac; in uniting sulphur with pot-ash, soda and lime; to compose sulphuret of pot-ash, soda and lime; to form fulminating mercury, silver and gold, and the prussiates of lime, potash, &c.

Thirdly. In procuring several of the acids, as the nitric, muriatic, oxymuriatic, oxalic, fluoric, acetic, &c.

Fourthly. In distilling water and spirituous liquors to form alcohol, &c. and uniting the sulphuric acid and alcohol to make ether, &c.

Fifthly. In the drying of powders, and in evaporating water, and some of the acids from saline solutions. A vessel of tin, copper, or glass, or a queen's-ware saucer, may be placed on the top of either of the stands for this purpose.

Sixthly. In making experiments upon all kinds of dying drugs, and

Seventhly. In analyzing earths and the ores of metals, in the humid way.

Plate II.

Fig. 1. The furnace A is formed of thick sheet iron, is ten inches high from the grate, and ten inches in diameter. There are two holes in its sides, to admit an earthen, iron or copper tube, and a door on one side to put in fuel, when a still, or any other piece of apparatus, is placed on its top. B is a brass funnel, and C a wire of the same metal, which enters into the tube of the funnel D, which is screwed into the gun-barrel E. F is a bent tube made of glass, tin, or copper, which is fixed in the mouth of the gun-barrel, and which enters under the shelf H, of the hydropneumatic tub G, which should be made of cedar, and the size of a common washing-tub, but of an oval form. I is a thumb screw, to fix another shelf J to the tub. K is a bell glass.

If water or any other fluid is put in the funnel B, it may, by turning the wire, be made to pass drop by drop, over any substance con-

very natural consequence of this primordial law, it follows that the elements of bodies must have been urged towards each other; that masses must have been formed by their re-union; and that solid and compact bodies must have insensibly been constituted; towards which, as towards a centre, the less heavy and less compact bodies must gravitate.

This law of attraction, which the chemists call Affinity, tends continually to bring principles together which are disunited, and retains with more or less energy those which are already in combination; so that it is impossible to produce any change in nature, without interrupting or modifying this attractive power.

It is natural, therefore, and even indispensable, that we should speak of the law of the affinities before we proceed to treat of the methods of analysis.

Affinity is exercised either between principles of the same nature, or between principles of a different nature.

We may, therefore, distinguish two kinds of affinity, with respect to the nature of bodies. 1. The affinity of aggregation, or that which exists between two principles of the same nature. 2. The affinity of composition, or that which retains two or more principles of different natures in a state of combination.

Of the Affinity of Aggregation.

Two drops of water which unite together into one, form an aggregate, of which each drop is known by the name of an integrant part.

fined in the gun-barrel, and the aërial product will be received in the bell glass K.

Fig. 2. A is a chafing dish, a few inches larger than the common size, containing a gun-barrel cut in two parts, and closed at one end by welding. B, a bent tube, which enters under the shelf of the hydropneumatic box C. D, a bell glass.

Fig. 3. A is a subliming vessel, shaped flat like a turnip.

Fig. 4. A is a cast iron matrass, sixteen inches in circumference, and a foot long, into the mouth of which the gun-barrel B is well ground, for making oxygen gas, carbonated hydrogen gas, oxyd of carbon, &c.

Fig. 5. A is an eight ounce vial, into the mouth of which the bent tube B enters, for making hydrogen gas, nitrous air, carbonic acid gas, &c.—*Am. Ed.*

An aggregate differs from a heap; because the integrant parts of this last have no perceptible adhesion to each other; as for example, a heap of barley, of sand, &c.

An aggregate and a heap differ from a mixture; because the constituent parts of this last are of a different nature; as, for example, in gunpowder.

The affinity of aggregation is stronger, the nearer the integrant parts approach to each other; so that every thing which tends to separate or remove these integrant parts from each other, diminishes their affinity, and weakens their force of cohesion.

Heat produces this effect upon most known bodies: hence it is that melted metals have no consistence. The caloric, or matter of heat, by combining with bodies, almost always produces an effect opposite to the force of attraction; and we might consider ourselves as authorized to affirm that it is a principle of repulsion, if sound chemistry had not proved that it produces this effect only by its endeavour to combine with bodies, and thereby necessarily diminishing their force of aggregation, as all other chemical agents do. Besides which, the extreme levity of caloric produces the effect that, when it is combined with any given body, it continually tends to elevate it, and to overcome that force which retains it, and precipitates it towards the earth.

The mechanical operations of pounding, of hammering, or of cutting, likewise diminish the affinity of aggregation. They remove the integrant parts to a distance from each other: and this new disposition, by presenting a less degree of adhesion, and a larger surface, facilitates the immediate action, and augments the energy of chemical agents. It is for this purpose that bodies are divided when they are to be analyzed, and that the effect of re-agents is facilitated by the action of heat.

The mechanical division of bodies is more difficult, the stronger their aggregation.

Aggregates exist under different states; they are solid, liquid, aëriform, &c.—See Fourcroy's Chemistry.

Of the Affinity of Composition.

Bodies of different kinds exert a tendency or attraction upon each other, which is more or less strong; and it is by virtue of this force that all the changes of composition or decomposition observed amongst them, are effected.

The affinity of composition exhibits invariable laws in all the phenomena it causes. We may state these laws as general principles; to which may be referred all the effects presented to our observation by the action of bodies upon each other.

I. The affinity of composition acts only between the constituent parts of bodies.

The general law of attraction is exerted upon the masses; and in this respect it differs from the law of the affinities, which does not perceptibly act but on the elementary particles of bodies. Two bodies placed near each other do not unite; but, if they be divided and mixed, a combination may arise. We have examples of this when the muriate of soda, or common salt, is triturated with litharge; the muriate of ammoniac, or common sal ammoniac, with lime, &c. And it may be asserted that the energy of the affinity of composition is almost always proportioned to the degree of the division of bodies.

II. The affinity of composition is in the inverse ratio of the affinity of aggregation.

It is so much the more difficult to decompose a body, as its constituent principles are united or retained by a greater force. Gases, and especially vapours, continually tend to combination, because their aggregation is weak: and nature, which is constantly renewing the productions of this universe, never combines solid with solid; but, reducing every thing into the form of gas, by this means breaks the impediments of aggregation; and these gases uniting together, form solids in their turn.

Hence, no doubt, it arises, that the affinity of composition is so much the more strong as bodies approach nearer to the elementary state; and we shall observe on this subject, that this law of nature is founded in wisdom; for if the force or affinity of composition did not

increase in proportion as bodies were brought to this degree of simplicity ; if bodies did not assume a decided tendency to unite and combine, in proportion as they approach to their primitive or elementary state ; the mass of elements would continually increase by these successive and uninterrupted decompositions ; and we should insensibly return again to that chaos or confusion of principles, which is supposed to have been the original state of this globe.

The necessity of this state of division, which is so proper to increase the force of affinity, has caused it to be admitted as an incontestible principle, that the affinity of composition does not take place, unless one of the bodies be in the fluid state : *corpora non agunt nisi sint fluida*. But it seems to me that extreme division might be substituted instead of dissolution ; for both these operations tend only to attenuate bodies, without altering their nature. It is by virtue of this division, which is equivalent to dissolution, that the decomposition of muriate of soda is effected by trituration with minium, as well as the union of cold and dry alkali with antimony, and the disengagement of volatile alkali by the simple mixture of sal ammoniac with lime.

III. When two or more bodies unite by the affinity of composition, their temperature changes.

This phenomenon cannot be explained but by considering the fluid of heat as a constituent principle of bodies, unequally distributed amongst them ; so that, when any change is produced in bodies, this fluid is displaced in its turn, which necessarily produces a change of temperature. We shall return to these principles when we speak of heat.

IV. The compound which results from the combination of two bodies, possesses properties totally different from those of its constituent principles.

Some chemists have affirmed, that the properties of compounds were intermediate between those of their constituent parts. But this term “ intermediate ” has no meaning in the present case ; for what intermediate qualities can exist between sour and sweet, or between water and fire ?

If we attend ever so little to the phenomena which are exhibited to us by bodies in their composition, we shall

perceive that their form, their taste, and their consistence, are changed in combination; and we cannot establish any rule to indicate, *a priori*, all the changes which may arise, and the nature and properties of the body which shall be formed.

V. Every individual substance has its peculiar affinities with the various substances presented to it.

If all bodies had the same degree of affinity with each other, no change could take place amongst them: we should not be able to displace any principle by presenting one body to another. Nature has therefore wisely varied the affinities, and appointed to each body its relation with all those that can be presented to it.

It is in consequence of this difference in the affinities that all chemical decompositions are effected; all the operations of nature and art are founded upon it. It is therefore of importance to be well acquainted with all the phenomena and circumstances which this law of decomposition can present to us.

The affinity of composition has received different names, according to its effects. It is divided into simple affinity, double affinity, the affinity of an intermedium, reciprocal affinity, &c.

1. Two principles united together, and separated by means of a third, afford an example of simple affinity: it consists in the displacing of one principle by the addition of a third. Bergman has given it the name of Elective Attraction.

The body which is disengaged, or displaced, is known by the name of the Precipitate. An alkali precipitates metals from their solutions; the sulphuric acid precipitates the muriatic, the nitric, &c.

The precipitate is not always formed by the disengaged substance. Sometimes the new compound itself is precipitated; as, for example, when I pour the sulphuric or vitriolic acid on a solution of muriate of lime. Sometimes the disengaged body and the new compound are precipitated together; as, for example, when the sulphate of magnesia or Epsom salt is dissolved in water, and precipitated by means of lime-water.

2. It often happens that the compound of two principles cannot be destroyed either by a third or a fourth

body separately applied; but if these two bodies be united, and placed in contact with the same compound, a decomposition or change of principles will then take place. This phenomenon constitutes the double affinity. An example will render this proposition more clear and precise. The sulphate of pot-ash or vitriolated tartar is not completely decomposed by the nitric acid or by lime, when either of these principles is separately presented; but, if the nitric acid be combined with lime, this nitrate of lime will decompose the sulphate of pot-ash. In this last case the affinity of the sulphuric acid with the alkali is weakened by its affinity to the lime. This acid, therefore, is subject to two attractions; the one which retains it to the alkali, and the other which attracts it towards the lime: Mr. Kirwan has named the first the *Quiescent Affinity*, and the other the *Divellent Affinity*. The same may be said respecting the affinities of the alkali; it is retained to the sulphuric acid by a superior force, but nevertheless attracted by the nitric acid. Let us suppose, now, that the sulphuric acid adheres to the alkali with a force as 8, and to the lime by a force expressed by the number 6; that the nitric acid adheres to the lime by a force as 4, and tends to unite with the alkali by a force as 7. It may then be perceived that the nitric acid and the lime, separately applied to the sulphate of pot-ash, would not produce any change: but if they be presented in a state of combination, then the sulphuric acid is attracted on the one hand by 6, and retained by 8; it has therefore an effective attraction to the alkali as 2. On the other hand, the nitric acid is attracted by a force as 7, and retained by a force as 4; it therefore retains a tendency to unite with the alkali, which is denoted by the number 3; and consequently it ought to displace the sulphuric acid, which is retained only by a force as 2.

3. There are cases in which two bodies, having no perceptible affinity to each other, obtain a disposition to unite by the intervention of a third; and this is called the affinity of an intermedium. An alkali is the intermedium of union between oil and water; hence the theory of *lixiviums*, of *washings*, &c.

If the affinities of bodies were well known, we might foretel the results of all operations: but it is obvious

how difficult it must be to acquire this extensive knowledge of nature; more especially since modern discoveries have exhibited to us an affinity of modifications in our processes, and have shewn that results may vary with such facility, that even the absence or presence of light will render them very different.

As long as chemistry was confined to the knowledge of a few substances, and was busied only in attending to a certain number of facts, it was possible to draw up tables of affinity, and to exhibit the result of our knowledge in one and the same table. But all the principles upon which these tables have been constructed, have received modifications; the number of principles has increased; and we find ourselves under the necessity of labouring upon new ground. A sketch of this great work may be seen in the Essay on Affinities of the celebrated Bergman, and in article Affinity in the *Encyclopédie Methodique*.

VI. The particles which are brought together and united by affinity, whether they be of the same nature or of different natures, continually tend to form bodies of a polyhedral, constant, and determinate form.

This beautiful law of nature, by which she impresses on all her productions a constant and regular form, appears to have been unknown to the ancients: and when chemists began to discover that almost all bodies of the mineral kingdom affected regular forms, they at first distinguished them according to the inaccurate resemblance supposed to exist between them and other known bodies. Hence the denomination of crystals in pyramids, needles, points of diamonds, crosses, sword blades, &c.

We are more particularly indebted to the celebrated Linnæus for the first precise ideas of these geometrical figures. He took notice of the constancy and uniformity of this character; and this celebrated naturalist thought himself authorized to make it the basis of his method of classification of the mineral kingdom.

Mr. Romé de Lisle has proceeded still farther: he has subjected all the forms to a strict examination; he has, as it were, decomposed them; and is of opinion that he can distinguish in the crystals of all analogous or identical substances, the simple modifications and shades of a

primitive form. By this means he has reduced all the confused and irregular forms to certain primitive figures; and has attributed to nature a plan or primitive design, which she varies and modifies in a thousand manners, according to circumstances that influence her proceedings. This truly great and philosophical work has rendered this part of mineralogy in the highest degree interesting; and if we should admit that Mr. De Lisle has perhaps carried these resemblances too far, we cannot but allow that he deserves a distinguished place amongst those authors who have contributed to the progress of science. The Crystallographic of this celebrated naturalist may be perused with advantage.

The abbé Haüy has since applied calculation to observation. He has undertaken to prove that each crystal has a nucleus or primitive form; and has shewn the laws of diminution to which the compotent laminae of the crystals are subject, in their transition from the primitive to the secondary forms. The development of these fine principles, and their application to crystals the best known, may be seen in his theory of the structure of crystals, and in several of his memoirs printed in the volumes of the Academy of Sciences.

The united labours of these celebrated naturalists have carried crystallography to a degree of perfection of which it did not appear susceptible. But we shall, at this moment, attend only to the principles according to which crystallization is effected.

To dispose a substance to crystallization, it is necessary in the first place to reduce it to the most complete state of division.

This division may be effected by solution, or by an operation purely mechanical.

Solution may be effected either by the means of water or of fire. The solution of salts is in general performed in the first liquid, that of metals is effected by means of the second; and their solution is not complete until a degree of heat is applied of sufficient intensity to convert them into the state of gas.

When the water which holds any salt in solution is evaporated, the principles of the dissolved body are insensibly brought nearer to each other, and it is obtained in

regular form. The same circumstance nearly takes place in the solution by fire. When a metal is impregnated with this fluid, it does not crystallize but in proportion as this excess of igneous fluid is withdrawn.

In order that the form of a crystal may be regular, three circumstances are required; time, a sufficient space, and repose. Consult Linnæus, Daubenton, &c.

A. Time causes the superabundant fluid to be slowly dissipated, and brings the integral parts nearer each other by insensible gradation, and without any sudden shock. These integrant parts therefore unite according to their constant laws, and form a regular crystal. For this reason it is, that slow evaporation is recommended by all good chemists. Vide Stahl's Treatise on salts, chap. 29.

In proportion as the evaporation of the solvent is effected, the principles of the dissolved body approach each other, and their affinity is continually augmented while that of the solvent remains unaltered. Hence it arises, no doubt, that the last portions of the solvent are most difficultly volatilized, and that salts retain a greater or less quantity, which forms their water of crystallization. The proportion of water of crystallization not only varies greatly in the different salts, but it adheres with greater or less strength. There are some which suffer this water to fly off when they are exposed to the air; such as soda or the mineral alkali, the sulphate of soda or Glauber's salt, &c. In this situation these salts lose their transparency, and fall into powder: they are then said to have effloresced. There are other salts which obstinately retain their water of crystallization; such as the muriate of pot-ash, the nitrate of pot-ash or common nitre, &c.

The phenomena presented to us by the different salts, when forcibly deprived of their water of crystallization, exhibit other varieties. Some crackle with the heat, and are thrown about in small pieces when the water is dissipated; this appearance is called decrepitation. Others emit the same water in the form of steam, and are liquefied with a diminution of their bulk. Others again swell up, and become converted into a blistered or porous substance.

We are indebted to Mr. Kirwan for an accurate table of the water of crystallization contained in each salt. This table may be seen by consulting his Mineralogy.

The simple cooling of the fluid which holds the salt in solution may precipitate a considerable quantity. The caloric and the water dissolve a greater quantity of salt when their action is united; and it may easily be imagined that the subtraction of one of the solvents must occasion the precipitation of that portion which it held in solution. Thus it is that warm water saturated with salt, must suffer a part to precipitate by cooling; and for this reason crystallization always begins at the surface of the liquid, and on the sides of the containing vessel; namely, because these parts are the first which suffer refrigeration.

It is the alternation of heat and cold which causes the atmosphere to dissolve sometimes a greater, and sometimes a less quantity of water; and constitutes mists, the evening dew, &c.

The mutual approach of the constituent parts of a body held in solution may be likewise accelerated by presenting to the water which suspends them, another body which has a stronger affinity to it. It is upon this principle that alcohol precipitates several salts.

B. Space or sufficient room is likewise a condition necessary for obtaining regular crystallization. If nature be restrained in her operations, the product of her labour will exhibit symptoms of this state of constraint. It may be asserted that nature forms her productions according to all the circumstances which may influence her operations.

C. A state of repose in the fluid is likewise necessary to obtain very regular forms. Uninterrupted agitation opposes all symmetrical arrangement; and in this case the crystallization obtained will be confused and indeterminate.

I am persuaded, that, in order to obtain bodies under the form of crystals, a previous solution is not necessary, but that a simple mechanical division would be sufficient. To obtain a conviction of this truth, it is only necessary to observe that solution does not change the nature of bodies, but simply procures an extreme state of division; so that the disunited principles approaching each other very gradually and without starts, can adapt themselves to each

other, by following the invariable laws of their gravity and affinity. Now a division purely mechanical produces the same effect, and places the principles in the same disposition. We ought not therefore to be surprised if most salts, such as gypsum, when dispersed in the earth, should assume regular forms without any previous solution; neither ought we to think it strange if the imperceptible fragments of quartz, of spar, &c. when carried along and prodigiously divided by the action of waters, should be deposited in the form of regular crystals.

A very singular property may be observed in salts; which may be referred to crystallization, but is likewise in some measure remote from it, because it does not depend upon the same causes. This is the property of rising along the sides of the vessels which contain the solution. It is known by the name of Saline Vegetation.

I have first demonstrated that this phenomenon depends on the concurrence of air and light; and that the effect may be determined at pleasure towards any part of the vessel, by managing and directing the action of these two agents.

I have shewn the principal forms which this singular vegetation affects. The detail of my experiments may be seen in the third volume of the *Memoirs of the Academy of Toulouse*.

Mr. Dorthes has confirmed my results; and has moreover observed that camphor, spirits of wine, water, &c. which rise by insensible evaporation in half-filled vessels, constantly attach themselves to the most enlightened parts of the vessels.

Messrs. Petit and Rouelle have treated on the vegetation of salts; but a series of experiments on the subject was wanting. This is what we have endeavoured to supply.

SECTION II.

Concerning the various Means employed by Chemists to overcome the Adhesion which exists between the Particles of Bodies.

THE law of affinities, towards which our attention has been directed, tends continually to bring the particles of body into contact, and to maintain them in their state of union. The efforts of the chemist are almost all directed to overcome this attractive power, and the means he employs are reducible to—1. The division of bodies by mechanical operations. 2. The division or separation of the particles from each other by the assistance of solvents. 3. The means of presenting to the several principles of the same bodies, substances which have a stronger affinity to them than those principles have to each other.

I. The different operations performed upon bodies by the chemist, to determine their nature, alter their form, their texture, and even in some instances change their constitution. All these changes are either mechanical or chemical.

The mechanical operations we shall at present describe, do not change the nature of substances, but in general change only their form and bulk. These operations are performed by the hammer, the knife, the pestle, &c. Whence it follows that the chemical laboratory ought to be provided with all these instruments.

These divisions or triturations are performed in mortars of stone, of glass, or of metal. It is the nature of the substance under examination which determines the use of one or the other of these vessels.

The object of these preliminary operations is, to prepare and dispose bodies for new operations which may disunite their principles and change their nature; these last-mentioned operations, which may be distinguished by the appellation Chemical, are what most essentially constitute the analysis.

II. The solution to which we are at present to attend, consists in the division and disappearance of a solid in a

liquid, but without any alteration in the nature of the body so dissolved.

The liquid in which the solid disappears, is called the solvent or menstruum.

The agent of solution appears to follow certain constant laws, which we shall here point out.

A. The agent of solution does not appear to differ from that of affinity; and in all cases the solution is more or less abundant, the greater the affinity of the integrant parts of the solvent is to those of the body to be dissolved.

From this principle it follows, that to facilitate solution, it is necessary that bodies should be triturated and divided. By this means a greater number of surfaces are presented, and the affinity of the integrant parts is diminished.

It sometimes happens that the affinity between the solvent and the body presented to it has so little energy that it does not become perceptible till after a considerable interval of time. These slow operations, of which we have some examples in our laboratories, are common in the works of nature; and it is probably to similar causes that we ought to refer most of those results whose causes or agents escape our perception or observation.

B. Solution is more speedy in proportion as the body to be dissolved presents a greater surface: on this principle is founded the practice of pounding, triturating, and dividing bodies intended to be dissolved. Bergman has even observed, that bodies which are not attacked in considerable masses, become soluble after minute division. *Letters on Iceland*, p. 421*.

C. The solution of a body constantly produces cold. Advantage has even been taken of this phenomenon to procure artificial cold, much superior to the most rigorous temperature ever observed in our climates. We shall again advert to this principle when we come to treat of the laws of heat.

The principal solvents employed in our operations are water, alcohol, and fire. Bodies submitted to one or the other of these solvents present similar phenomena; they

* Von Troil's Letters, quoted by Mr. Bergman. T.

are divided, rarefied, and at last disappear: the most refractory metal melts, is dissipated in vapour, and passes to the state of gas, if a very strong heat be applied to it. This last state forms a complete solution of the metallic substance in the caloric.

The effect of caloric is often united with one of the other solvents, to accomplish a more speedy and abundant solution.

The three solvents here mentioned do not exercise an equal action on all bodies indiscriminately. Skilful chemists have exhibited tables of the dissolving power of these menstruums. We may see, in the Mineralogy of Kirwan, with what care that celebrated chemist has exhibited the degree of solubility of each salt in water. The table of Mr. De Morveau may likewise be consulted on the dissolving power of alcohol. *Journal de Physique*, 1785.

Most authors who have treated of solution have considered it in too mechanical a point of view. Some have supposed sheaths in the solvent, and points in the body dissolved. This absurd and gratuitous supposition has appeared sufficient to account for the action of acids upon bodies. Newton and Gassendi have admitted pores in water, in which salts might insinuate themselves; and have by this means explained why water does not augment in its bulk in proportion to the quantity of salt it takes up. Gassendi has even supposed pores of different forms; and has endeavoured to shew by this means how water saturated with one salt may dissolve others of another kind. Dr. Watson, who has observed the phenomena of solution with the greatest care, has concluded from his numerous experiments; 1. That the water rises in the vessel at the moment of the immersion of the salt. 2. That it falls during the solution. 3. That it rises after the solution above the original level. The two last effects seem to me to arise from the change of temperature which the liquor undergoes. The refrigeration arising from the solution must diminish the volume of the solvent; but it ought to return to its first state as soon as the dissolution is finished. The tables of Dr. Watson respecting these phenomena, and the specific gravity of water saturated

with different salts, may be consulted in the *Journal de Physique*, vol. xiii. p. 62.*

III. As the peculiar affinities of bodies to each other are various, the constituent principles may be easily disengaged by other substances; and it is upon this consideration that the action of all the re-agents employed by chemistry in its analysis is founded. Sometimes the chemist displaces certain principles, which he can in that state examine more accurately, because insulated, and disengaged from all their combinations. It frequently happens that the re-agent made use of combines with some principle of the body analyzed; and a compound arises, whose characters indicate to us the nature of the principle which has thus entered into combination, because the combinations of the principal re-agents with various bases are well known. It likewise frequently happens that the re-agent made use of is itself decomposed, which circumstance renders the phenomena and the products more complicated; but we are enabled from the nature of these products to form a judgment of the component parts of the body analyzed. This last fact was little attended to by the ancient chemists; and this is one of the principal defects of the labours of Stahl, who has referred most of those phenomena to the bodies which he submitted to analysis, which in reality arose only from the decomposition of the re-agents employed in his operations.

SECTION III.

Concerning the Method of Proceeding which the Chemist ought to follow in the Study of the various Bodies presented to us by Nature.

THE progress made in any science depends upon the solidity of those principles which form its basis, and upon the method of studying them. It is not, therefore,

* Or in the fifth vol. of his *Chemical Essays*. T.

to be wondered at, that chemistry made but little progress in those times, when the language of chemists was enigmatical, and when the principles of the science were founded only on analogies falsely deduced, or on a few facts illy understood. In the times which have followed this epocha, the facts have indeed been more attended to; but, instead of suffering them to speak for themselves chemists have been desirous of making applications, drawing consequences, and establishing theories. Thus it was that Stahl, when he first observed that oil of vitriol and charcoal produced sulphur, if he had then confined himself to the simple relation of the fact, he would have announced a valuable and eternal truth; but when he concluded that the sulphur was produced by the combination of the inflammable principle of the charcoal with the oil of vitriol, he asserted that which the experiment does not point out: then it was that he proceeded further than the facts warranted; and this first rash step might be a first step towards error. All doctrine, in order to be lasting, ought to consist of the pure and simple expression of facts: but we are almost always governed by our imaginations; we adapt the facts to our manner of seeing them, and thus we are misled by ourselves. The prejudice of self-love afterwards furnishes us with various means to avoid recantation; we exert ourselves to draw our successors into the same paths of error; and it is not till after much time has been lost, after many vain conjectures have been exhibited, and after we have the strongest convictions that it is impossible to bend the nature of things to our caprices and unfounded ideas, that some superior mind disengages itself from the delusion; and returning to experiment, and the nature of things, suffers himself to be led no further than he is authorized by these to proceed.

We may affirm, to the honour of our cotemporaries, that facts are at present discussed by a much severer logic; and it is to this vigorous method of investigation and discussion that we are indebted for the rapid progress of chemistry. It is in consequence of this dialectic march that we have at length arrived to the practice of attending to all the principles which are combined or disengaged in the operations of nature and art. We keep an account

of all the circumstances which have a more or less considerable influence on the results, and we deduce simple and natural consequences from the whole of the facts; by which means we create a science as strict in its principles, as sublime in its applications.

This then is the moment to draw out a faithful sketch of the actual state of chemistry, and to collect in the numerous writings of modern chemists every thing which may serve to lay the foundation of this beautiful science.

Not many years ago, it was possible to present, in a few words, the whole of our knowledge of chemistry. It was sufficient, at that time, to point out the methods of performing pharmaceutical operations; the processes of the arts were almost all enveloped in darkness, the phenomena of nature were all enigmatical; and it is only since this veil has begun to be removed that we have beheld the development of a collection of facts and researches referable to general principles, and forming a science entirely new. Then it was that a number of men of genius reviewed the whole, and attended to the improvement of chemical knowledge. Every step in their progress brought them nearer to the truth; and in a few years we have beheld a perspicuous doctrine arise out of the ancient chaos. Every event has appeared conformable to the laws they established; and the phenomena of art and nature are now explained with equal facility.

But in order to advance with speed in the career which has been thus opened, it is necessary to explain certain principles, according to which we may direct our steps.

In the first place I think it proper to avoid that tedious custom which subjects the beginner in any science to the painful task of collecting all the opinions of various philosophers before he decides for himself. In reality, facts belong to all times, and are as unchangeable as nature herself, whose language they are. But the consequences deduced from them must vary according to the state of our acquired knowledge. It is eternally true for example, that the combustion of sulphur affords the sulphuric acid. It was believed, for a certain time, that this acid was contained in the sulphur; but our discoveries on the combustion of bodies ought to have led us to the deduction of a

very different theory from that which presented itself to the earlier chemists. We ought, therefore, to attach ourselves principally to facts; or rather we ought to attach ourselves to the facts only, because the explanation which is given of them at remote times is very seldom suited to the present state of our knowledge.

The numerous facts with which chemistry has been successively enriched, form the first embarrassment of the student who is desirous of acquiring the elements of this science. In fact, what are the elements of a science? The clear, simple, and accurate enunciation of those truths which form its basis. It is necessary, therefore, for the full accomplishment of this purpose, to analyze all the facts and to exhibit a faithful and clear abridgment: but this method is impracticable on account of the numerous details, and the infinite number of discussions, into which it would lead us. The only proceeding, therefore, which appears to me to be practicable, is to exhibit the most decisive experiments, those which are the least contested, and to neglect those which are doubtful or inconclusive: for one experiment, well made, establishes a truth as uncontestably as a thousand equally averred.

When a proposition is found to be supported by suspicious or contested facts, when opposite theories are built upon contradictory experiments, we must have the courage to discuss them, to repeat them, and to acquire a certainty of the truth by our own endeavours. But when this method of conviction is out of our power, we ought to weigh the degree of confidence which the defenders of the opposite facts are entitled to; to examine whether analogous facts do not lead us to adopt certain results; after which it becomes us to give our opinion with that modesty and circumspection, suitable to the greater or less degree of probability annexed to each opinion.

But when any doctrine appears to us to be established on experiments of sufficient validity, it then remains to be applied to the phenomena of nature and art. This, in my opinion, is the most certain touchstone to distinguish true principles from those which are without foundation. And when I observe that all the phenomena of nature unite, and conform themselves, as it were, to any theory, I conclude that this theory is the expression and the language of

truth. When, for example, I behold that a plant can be supported by pure water alone, that metals are calcinable by water, that acids are formed in the bowels of the earth, have I not a right to conclude that the water is decomposed? and do not the chemical facts which in our laboratories afford a testimony of its decomposition—do not these acquire a new force by the observation of the preceding phenomena? I conclude, therefore, that we ought to make a point of uniting these two kinds of proofs: and a principle deduced from experiment is not, in my opinion, demonstrable until I see that it may with facility be applied to the phenomena of art and nature. Hence, if I find myself in a state of hesitation between opposite systems, I will decide in favour of that whose principles and experiments adapt themselves naturally, and without force to the greatest number of phenomena. I will always distrust a single fact, which is applicable to no conclusion; and I will consider it as false, if it be in opposition to the phenomena which nature presents to us.

It appears to me likewise that he who professes to study, or even to teach chemistry, ought not to endeavour to arrive at or exhibit the whole which has been done in each department, or to follow the tedious progress of the human mind from the origin of a discovery to the present time. This fastidious erudition is fatiguing to the learner; and these digressions ought in no case to be admitted in the enunciation of science, excepting when the historical details afford interesting facts, or lead us by uninterrupted degrees to the present state of our knowledge. It rarely happens, however, that this kind of researches, this genealogy of science, affords us such characters; and it ought no more to be admitted, in general, that an elementary writer should bring together and discuss every thing which has been done in a science, than that he who undertakes to direct a traveller should previously enter into a long dissertation on all the roads which have been successively made, and on those which still exist, before he should point out the best and shortest way to arrive at the end of his journey. It may, perhaps, be said of the history of science, and more especially that of chemistry, that it resembles the histories of nations. It seldom affords any light respecting the present situation of affairs; exhibits

many fables concerning past times ; induces a necessity of entering into discussions upon the circumstances that pass in review ; and supposes a mass of extraneous knowledge acquired on the part of the reader, which is independent of the purpose aimed at in the study of the elements of chemistry.

When these general principles, respecting the study of chemistry, are once well established, we may afterwards proceed in the chemical examination of bodies in two ways : we may either proceed from the simple to the compound, or we may descend from the compound to the simple. Both these methods have their inconveniences ; but the greatest, no doubt, which is found in following the first method is, that, by beginning with the simplest bodies, we present substances to the consideration of the learner which nature very seldom exhibits in such a state of nakedness and simplicity ; and we are forced to conceal the series of operations which have been employed to divest these substances from their combinations, and reduce them to the elementary state. On the other hand, if we present bodies to the view of the learner such as they are, it is difficult to succeed in an accurate knowledge of them ; because their mutual action, and in general most of their phenomena, cannot be understood without the previous and accurate knowledge of their constituent principles, since it is upon these alone that they depend.

After having maturely considered the advantages and inconveniences of each method, we give the preference to the first. We shall therefore begin by giving an account of the several bodies in their most elementary state, or reduced to that term beyond which analysis can effect nothing ; and, when we shall have explained their various properties, we will combine these bodies with each other, which will afford a class of simple compounds : and hence we shall rise by degrees to the knowledge of bodies, and the most complicated phenomena. We shall be careful, in any examination of the several bodies to which we shall direct our researches, to proceed from known to unknown ; and our first attention shall be directed to elementary substances. But as it is impossible, at one and the same time, to treat of all those substances which the

present state of our knowledge obliges us to consider as elementary, we shall confine ourselves to the exhibition of such as are of the greatest importance in the phenomena of the globe we inhabit, such as are almost universally spread over its surface, and such as enter as principles into the composition of the re-agents most frequently employed in our operations; such, in a word, as we continually find in the examination and analysis of the component parts of the globe. Light, heat, sulphur, and carbone are of this number. Light modifies all our operations, and most powerfully contributes to the production of all the phenomena which appertain to bodies either living or inanimate. Heat, distributed after an unequal proportion among all the bodies of this universe, establishes their various degrees of consistence and fixity; and is one of the great means which art and nature employ to divide and volatilize bodies, to weaken their force or adhesion, and by that means prepare them for analysis. Sulphur exists in the products of the three kingdoms; it forms the radical of one of the best known, and most generally employed, acids; it exhibits interesting combinations with most simple substances; and, under these several points of view, it is one of the substances the most necessary to be known in the first steps of chemical science. The same may be said of carbone; it is the most abundant fixed product found in vegetables and animals. Analysis has discovered it in some mineral substances. Its combination with oxigene is so common in bodies, and in the operations of art and nature, that there are scarcely any phenomena which do not present it to our view, and which consequently require the knowledge of its properties. From all these reasons it appears to us, that for the advancement of chemistry it is necessary our first proceeding should be founded on the knowledge of these substances: and that we should not direct our attention to other simple or elementary substances, accordingly as they present themselves.

SECTION IV.

Concerning Simple or Elementary Substances.

IF we cast an eye over the systems which have been successively formed by philosophers relative to the number and nature of the elements, we shall be astonished at the prodigious variety which prevails in their manner of thinking. In the earlier times, every one seems to have taken his own imagination for his guide ; and we find no reasonable system until the time when Aristotle and Empedocles acknowledged as elements, Air, Water, Earth, and Fire. Their opinion has been well received for many ages ; and it must be confessed that it is calculated to seduce the mind. There are, in fact, enormous masses, and inexhaustible stores, that present themselves to our view, of these four principles, to which the destruction or decomposition of bodies appeared to refer all the several component parts which formation or creation had taken from them. The authority of all those great men who had adopted this system, and the analysis of bodies which presented only these four principles, afforded sufficient grounds for admitting this doctrine.

But as soon as chemistry had advanced so far as to discover the principles of bodies, the professors of that science presumed to mark the number, nature, and character of the elements ; and every substance that was unalterable by the chemical methods of decomposition, was considered by them as a simple or elementary principle. By thus taking the limits of analysis as the term for indicating the elements, the number and the nature of these must vary according to the revolutions and the progress of chemistry. This has accordingly happened, as may be seen by consulting all the authors who have written on this subject, from the time of Paracelsus to the present day. But it must be confessed that it is no small degree of rashness, to assume the extent of the power of the artist as a limit for that of the Creator, and to imagine that the state of our acquisitions is a state of perfect knowledge.

The denomination of Elements ought therefore to be effaced from a chemical nomenclature, or at least it ought not to be used but as an expression denoting the last term of our analytical results ; and it is always in this sense that we shall use the word.

CHAPTER I.

Concerning Fire.

THE principal agent employed by nature to balance the power and natural effect of attraction, is fire. By the natural effect of attraction we should possess none but solid and compact bodies ; but the caloric unequally dispersed in bodies tends incessantly to destroy this adhesion of the particles ; and it is to this principle that we are indebted for the varieties of consistence under which bodies present themselves to our observation. The various substances that compose this universe are therefore subjected, on the one hand, to a general law which tends to bring them together ; and, on the other hand, to a powerful agent which tends to remove them from each other : it is upon the respective energy of these two forces that the consistence of all bodies depends. When the affinity prevails, they are in the solid state ; when the caloric is most powerful, they are in the state of gas ; and the liquid state appears to be the point of the equilibrium between these two powers.

It is therefore essentially necessary to treat of fire, since it acts so leading a part in this universe ; and because it is impossible to treat of any substance whatever, without attending to the influence of this agent.

There are two things to be considered in fire—heat and light.

These two principles, which have been very often confounded, appear to be very distinct in their own nature ;

because they are scarcely ever proportional to each other, and because each can exist without the other.*

The most usual acceptation of the word Fire comprehends heat and light; and its principal phenomena must have been known for a long time. The discovery of fire must have been nearly as ancient as the human species upon this globe. The shock of two flints, the action of meteors, or the effect of volcanos, must have afforded the earliest idea of it; and it is very astonishing that the inhabitants of the Marian islands were not acquainted with its effects before the invasion of the Spaniards. These islanders, who became acquainted with this terrible element only in consequence of its ravages, considered it at first as a malevolent being which attached itself to all beings, and devoured them.—See the Abbé Raynal's *Histoire Philosophique*, &c.

The effects of fire are perhaps the most astonishing of any which nature exhibits; and we ought not to be surprised that the ancients considered it as an intermediate being between spirit and matter, and have built the beautiful fable of Prometheus upon its origin. We have had the happiness, in our time, to acquire well founded and extensive ideas respecting this agent, which we shall proceed to develop in the two following articles.

ARTICLE I.

Concerning Caloric and Heat.

When a metal or a liquid is heated, these bodies are dilated in every direction, are reduced to vapour, and at last become invisible when the most powerful heat is applied to them.

Bodies which possess the principle of heat, part with it more or less readily. If we attentively observe a body during its cooling, a slight movement of undulation will be perceived in the surrounding air; an effect which may be

* We see heat without light in iron heated very hot, and light without heat in rotten wood, the solar phosphori, the fire-fly and glow-worm, putrid fish, &c. The rays of the moon collected into a focus by a concave mirror, give light without heat.—*Am. Ed.*

compared to the phenomenon exhibited upon the mixture of two liquors of unequal density and weight.

It is difficult to conceive this phenomenon, without admitting of a peculiar fluid, which passes first from the body which heats to that which is heated, combines with the latter, produces the effects we have spoken of, and afterwards escapes to unite with other bodies, according to its affinities, and the law of equilibrium, to which all bodies tend.

This fluid of heat, which we call Caloric, is contained in greater or less quantities in bodies, according to the greater or less degrees of affinity existing between it and them.

Various means may be employed to displace or disengage the caloric. The first is by the method of affinities: for example, water poured upon the sulphuric acid expels the heat, and takes its place; and while there is a disengagement of heat, the volume of the mixture does not increase in proportion to the bulk of the two substances mixed. This shews that penetration takes place, which cannot be explained but by admitting that the integrant parts of the water take the place of the caloric, in proportion as it is dissipated.—The second method of precipitating caloric, is by friction and compression. In this case it is expressed or squeezed out, in the same manner as water from a sponge. In reality, the whole of the heat which may be produced by friction, is not afforded by the body itself; because, in proportion as the interior heat is developed, the external air acts upon the body, calcines or inflames it, and itself gives out heat during its fixation. Fermentation, and in general every operation which changes the nature of bodies, may disengage caloric, because the new compound may demand and receive a greater or less quantity. Hence it is that chemical operations produce sometimes cold, and sometimes heat.

Let us now examine the form under which caloric presents itself.

This fluid is disengaged either in a state of liberty, or in a state of combination.

In the first case, the caloric always endeavours to obtain an equilibrium; not that it is distributed equally among all bodies, but it is dispersed among them according to the

degrees of its affinity. Whence it follows, that the circumambient bodies receive and retain a quantity more or less considerable. Metals are easily penetrated by this fluid, and transmit it with equal facility; wood and animal substances receive it to the degree of combustion; liquids, until they are reduced to vapour. Ice absorbs all the heat communicated to it, without giving it out to other bodies until it has acquired the fluid state.

The degree of heat can be appreciated only by its effects: and the instruments which have been successively invented to calculate it, and are known by the names of thermometers, pyrometers, &c. have been applied to the strict determination of the several phenomena exhibited in consequence of the absorption of caloric in various bodies.

The dilatation of fluids, or of metals in the fluid state, by the several degrees of heat, has been long measured by thermometers formed of glass; but this very fusible substance can only be used to ascertain degrees of heat inferior to that which renders the glass itself fluid.

Several means have been successively proposed for calculating the higher degrees of heat. Mr. Leidenfrost has proved, that the hotter a metal is, the more slowly will drops of water evaporate from its surface; and he has proposed this principle for the construction of pyrometers. A drop of water in an iron spoon, heated to the degree of boiling water, evaporates in one second; a similar drop, poured on melted lead, is dissipated in six or seven seconds; and upon red-hot iron in thirty. Mr. Ziegler, in his *Specimen de digestore Papini*, has found that 89 seconds were required to evaporate a drop of water at 520 degrees of Fahrenheit; and that one second is sufficient at the 300th degree. This phenomenon, which is more interesting to chemistry than pyrometry, to which it will always afford results little susceptible of rigorous calculation, appears to me to depend upon the adhesion and decomposition of the water upon the metal.

The most accurate pyrometer we are acquainted with, is that which was presented to the Royal Society of London by Mr. Wedgwood. It is constructed upon the principle, that the purest clay shrinks in the fire in proportion to the heat applied to it. This pyrometer consists of two

parts; one called the gauge, which serves to measure the degrees of diminution or shrinking; the other contains the simple pieces of pure clay, which are called thermometer pieces.

The gauge is formed of a plate of baked earth, upon which are applied two rulers or straight pieces of the same substance.* These rulers, being perfectly straight and even, are placed at the distance of half an inch from each other at one of their ends, and three-tenths of an inch at the other. For greater convenience, the gauge is divided into two parts, and the two pieces are placed endways when required to be used. The length of this rule is divided into 240 equal parts, of which each represents one-tenth of an inch. To form the thermometer pieces, the earth is sifted with the greatest attention, after which it is mixed with water, and the paste thrust through an iron tube, which gives it a cylindrical form, to be cut afterwards into pieces of a proper size.† When the pieces are dry, they must be presented to the gauge, where they ought to fit at the place of 0 on the scale. If by inadvertence of the workmen any piece penetrates to one or two degrees further, this degree is marked on its flat surface, and requires to be deducted when the piece is used in the admeasurement of heat. The pieces thus adjusted are baked in a furnace to a red heat, to give them the consistence necessary for carriage. The heat employed in this part of the process is usually about six degrees, and the pieces are diminished more or less; but this is of no consequence when they come to be submitted to a superior degree of heat; and if it should happen that an inferior degree of heat is required to be measured, unbaked pieces are to be used, which are preserved in sheaths or cases to avoid friction.

When this pyrometer is to be used, one of the pieces is exposed in the fire-place whose heat is required to be determined; and when it has acquired the whole intensity, it

* Or of two brass rulers screwed down upon a flat piece of the same metal.

† The earth is passed through finer and finer sieves, the last of which is a silk lawn, the interstices of whose threads are less than 150,000 parts of a square inch.—*Am. Ed.*

is taken out, or suffered to cool, or for greater speed it is plunged in water; after which it is presented to the gauge, and its degree of contraction easily determined. Mr. Wedgwood has given us the result of several experiments made with his pyrometer, opposite to which he has placed the correspondent degrees of Fahrenheit.

	<i>Pyrometer Of Wedgwood.</i>	<i>Thermometer Of Fahrenheit.</i>
Red heat visible by the light	0	1077
Brass melts at	21	1857
Swedish copper melts at	27	4587
Pure silver melts at	28	4717
Pure gold melts at	32	5237
The heat of bars of iron raised to	90	12777
welding	95	13427
The greatest heat producible in a smith's forge	125	17527
Cast iron melts at	130	17977
The greatest heat of a wind furnace of eight inches square	160	21877

These various thermometers are not applicable to all cases. We cannot, for example, calculate with strictness the heat which escapes from living bodies, or determine with precision the temperature of any substance. But Messrs. De la Place and Lavoisier (*Acad. des Sciences*, 1780) have invented an apparatus which appears to leave nothing further to be desired. It is constructed upon the principle that ice absorbs all the heat communicated to it, without communicating it to other bodies until the whole is melted; so that from hence we may calculate the degrees of heat communicated, by the quantity of ice which is melted. It was necessary, in order to afford strict results, to discover the means of causing the ice to absorb all the heat disengaged from the bodies under examination, and to cover it from the action of every other substance which might facilitate its fusion; and, lastly to collect with great care the water produced by the fusion.

The apparatus constructed by these two celebrated academicians for this purpose, consists of three circular vessels nearly inscribed in each other; so that three capacities are produced. The interior space or capacity is formed by an iron grating, upon supports of the same metal. Here it is that the bodies subjected to experiment are

placed. The upper part of this cavity is closed by means of a cover. The middle space, next to this, is designed to contain the ice which surrounds the interior compartment. This ice is supported and retained by a grate, upon which a cloth is spread. In proportion as the ice melts, the water flows through the grate and the cloth, and is collected in a vessel placed beneath. Lastly, the external space or compartment of the apparatus contains ice intended to prevent the effect of the external heat of the atmosphere.

To use this excellent machine, the middle or second space is filled with pounded ice, as is likewise the cover of the internal sphere; the same thing is done with regard to the external space, as well as to the general covering of the whole machine: the interior ice is suffered to drain; and, when it ceases to afford water, the covering of the internal space is raised, to introduce the body upon which the experiment is intended to be made. Immediately after this introduction, the covering is put on, and the whole apparatus remains untouched until the included body has acquired the temperature of 0, or the freezing temperature of water; which is the common temperature of the internal capacity. The quantity of water afforded by the melting of the ice is then weighed; and this is an accurate measure of the heat disengaged from the body, because the fusion of the ice is the effect of this heat only. Experiments of this kind last fifteen, eighteen, or twenty hours.

It is of great consequence, that in this machine there should be no communication between the middle, or second, and the external space.

It is likewise necessary that the air of the apartment should not be lower than 0, because the interior ice would then receive a degree of cold lower than that temperature.

Specific heat is merely the proportional quantity of heat necessary to raise bodies of equal mass to the same number of degrees of temperature; so that, when the specific heat of a solid body is required, its temperature must be elevated a certain number of degrees, at which instant it must be placed in the internal sphere, and there left until its temperature is reduced to 0. The water is then collected, and this quantity divided by the product.

of the mass of the body; and the number of degrees of its original temperature above 0, will be proportional to its specific heat.

With regard to fluids, they are inclosed in vessels whose heat has been previously determined. The operation is then the same as for solids; excepting that the quantity of water afforded must be diminished by a deduction of that quantity which has been melted by the heat of the vessel.

If it be required to determine the heat which is disengaged during the combination of various substances, they must be all reduced, as well as their containing vessels, to the temperature of 0. The mixture must then be placed in the internal sphere; and the quantity of water collected is the measure of the disengaged heat.

In order to determine the heat of combustion and respiration, as the renewal of air is indispensable in these two operations, it is necessary to establish a communication between the internal part of the sphere and the surrounding atmosphere; and in order that the introduction of fresh air may not cause any perceptible error, these experiments ought to be made at a temperature little differing from 0, or at least the air which is introduced must previously be brought to this temperature.

To determine the specific heat of any gas, it is necessary to establish a current through the internal part of the sphere, and to place two thermometers, one at the place of introduction, and the other at the place of escape. By comparison of the temperatures exhibited by these two instruments, a judgment is formed of the heat absorbed, and the melted ice is measured.

An excellent memoir of Messrs. De la Place and Lavoisier may be consulted for the results of the experiments they have made. The present extract contains only a short account of their valuable labours.

The various means made use of for the admeasurement of heat, are founded on the general principle, that different bodies absorb heat in greater or less quantities. If this fact were not generally admitted, it might be established on the three following facts. Dr. Franklin having exposed two small pieces of cloth, of the same texture but of different colours, upon the surface of snow, perceived, a few hours afterwards, that the red cloth was buried in

the snow, while the other which was white had not suffered any depression*. M. de Saussure observes, that the peasants of the mountains of Switzerland, are careful to spread a black earth over the surface of grounds covered with snow, when they are desirous of melting it, to sow their seed. So likewise children burn a black hat in the focus of a small lens which would scarcely heat a white one.

Such nearly are the phenomena of heat when it is disengaged in a state of liberty. Let us now contemplate those which it presents when it escapes from a state of combination.

Heat is sometimes disengaged in a state of simple mixture, as in the phenomena of vapours, sublimations, &c. If heat be applied to water, these two fluids will unite, and the mixture will be dissipated in the atmosphere; but it would be an abuse of words to call so weak an union by the name of combination; for, as soon as the heat becomes in a situation to combine with other bodies, it abandons the water, which returns to a liquid state. This body, during evaporation, continually carries with it a portion of heat; and hence, perhaps, result the advantages of transpiration, perspiration, &c.

But heat very frequently contracts a true chemical union with the bodies which it volatilizes: this combination is even so perfect, that the heat is not perceptible, but is neutralized by the body with which it is combined. It is then called latent heat, *calor latens*.

The several cases in which heat enters into combination, and passes to the state of latent heat, may be reduced to the two following principles:

The first principle.—Every body which passes from the solid to the liquid state, absorbs a portion of heat, which is no longer sensible to the thermometer, but exists in a true state of combination.

The academicians of Florence filled a vessel with pounded ice, and plunged a thermometer in it, which descended to 0. The vessel was then immersed in boiling water, and the thermometer did not rise during the whole time of

* They were exposed to the rays of the sun. T.

the liquefaction of the ice. The fusion of ice therefore absorbs heat.

Mr. Wilcke poured a pound of water, heated to the 60th degree of Reaumur, upon a pound of ice. The melted mixture possessed the temperature of 0. Sixty degrees of heat had therefore entered into combination.

The Chevalier Laudriani has shewn that the fusion of metals, of sulphur, of phosphorus, of alum, of nitre, &c. absorb heat.

Cold is produced in the dissolution of all the (crystallized) salts.

Reaumur made a series of very interesting experiments on this subject, which confirm those of Boyle. Fahrenheit caused the thermometer to descend to forty degrees, by melting ice by strong nitrous acid. But the most astonishing experiments are those made by Mr. Walker, an apothecary at Oxford, and inserted in the Philosophical Transactions for the year 1787*. The mixtures which produced the greatest degrees of cold are, 1. Eleven parts of muriate of ammoniac, or common sal ammoniac; ten parts of nitrate of potash, or common nitre; sixteen parts of sulphate of soda, or Glauber's salt; with thirty-two parts by weight of water: the two first salts should be dry and in powder. 2. The nitric acid, muriate of ammoniac, and sulphate of soda, lowered the thermometer to eight degrees under 0. Mr. Walker has frozen mercury without using either ice or snow.†

It is therefore an incontrovertible principle, that all bodies which pass from the solid to the liquid state, absorb heat, and retain it in so accurate a combination as to afford no sign of its presence. The heat is therefore fixed, neutralized, or latent.

The second principle.—All bodies, by passing from the solid or fluid state to the æriform state, absorb heat, which becomes latent; and it is by virtue of this heat that such bodies are placed and maintained in that state.

On this principle is founded the process used in China, India, Persia, and Egypt, to cool liquors used for drink.

* Also in the subsequent volumes.

† Many experiments have been made by the chemists, in order to produce artificial cold. The following table will shew how low the

The water intended for this purpose is put into very porous vessels, and exposed to the sun, or to a

mercury in Fahrenheit's thermometer, may be reduced by a mixture of the acids, water, and neutral salts ;

Muriate of ammoniac	5 parts	From 50° to 10°.
Nitrate of potash	5	
Water	16	
Muriate of ammoniac	5 parts	From 50° to 4°.
Nitrate of potash	5	
Sulphate of soda	8	
Water	16	
Sulphate of soda	3 parts	From 50° to 3°.
Nitric acid diluted	2	
Sulphate of soda	8 parts	From 50° to 0°.
Muriatic acid	5	
Snow	1 part	From 32° to 0°.
Muriate of soda	1	
Snow or pounded ice	2 parts	From 0° to —5°.
Muriate of soda	1	
Pounded ice or snow	1 part	From —5° to —18°.
Muriate of soda	5	
Muriate of ammoniac	5	
Nitrate of potash	5	
Snow or pounded ice	12 parts	From —18° to —25°.
Muriate of soda	5	
Nitrate of ammonia	5	
Snow and diluted nitric acid		From 0° to —46°.
Muriate of lime	3 parts	From —32° to —50°.
Snow	2	
By means of this mixture a degree of cold has been produced equal to 90 deg. below 0.		
Snow	1 part	From —20° to —60°.
Diluted sulphuric acid	1	

The best and cheapest mixture to produce artificial cold, for cooling liquors, is the sulphuric acid diluted with an equal bulk of water, and suffered to cool, and Glauber's salt in fine powder, retaining its water of crystallization. Five parts of Glauber's salt, and four of the diluted sulphuric acid, will sink the mercury in a thermometer from 50° to 3°.—*Am. Ed.*

current of warm air, to cool the fluid contained within them.*

It is by similar means that cool drink is obtained in the long journeys of the caravans. Interesting details on this subject may be seen in the *Travels of Chardin*, vol. iii. 1723; *Tavernier's Voyages*, vol. i. edit. 1738; *Paul Lucas's Voyages*, vol. ii. edit. 1724; and also in the *Mundus Subterraneus* of P. Kircher, lib. vi. sec. 2. cap. 2.

We may conclude from the experiments of Mr. Richmann, made in 1747, and inserted in the first volume of the imperial Academy of Petersburg, 1. That a thermometer taken out of water, and exposed to the air, always descends, even when its temperature is equal or superior to that of the water. 2. That it afterward rises, until that it has acquired the temperature of the atmosphere. 3. That the time of descending is less than that which it employs to rise again. 4. That when the thermometer, withdrawn from the water, has arisen to the common temperature, its bulb is dry; but that it continues wet during the whole time of its standing beneath this common temperature.

To these consequences we will add others deduced from several curious experiments by the celebrated Cullen. 1. A thermometer suspended in the receiver of the air pump, descends two or three degrees during the time of exhaustion, and afterwards rises to the temperature of the vacuum. 2. A thermometer plunged in alcohol, in the receiver of the air pump, always descends, and the lower in proportion as the bubbles are stronger which issue from the alcohol; if it be withdrawn from this liquor, and suspended wet beneath the receiver, it falls eight or ten degrees while the air is pumping out.

It is well known that if the ball of a thermometer be wrapped in fine linen, and kept moist by sprinkling with ether, and the evaporation be facilitated by agitation in the air, the thermometer will descend to 0.†

* Water cannot be cooled in the United States, by permitting it to transude and evaporate from the surface of porous vessels. They merely prevent it from becoming very hot. Whether the vessels are placed in the sun or the shade, the temperature of the water will rise in the months of July or August, from 52° to 80° in the space of a few hours.—*Am. Ed.*

† The best mode of performing this experiment, is to sprinkle the linen, with which the bulb of the thermometer is covered, with a mixture of equal parts of the sulphuric and muriatic ethers.—*Am. Ed.*

The immortal Franklin has proved, in his own person, that when the body perspires strongly, it is less heated than surrounding bodies, and that perspiration always produces a certain degree of coldness. See his letter to Dr. Lind.

The great number of labourers in the burning heats of our climate support themselves only by virtue of a copious perspiration, the fluid for which they replenish by drinking plentifully. The workmen employed in glass-houses, founderies, &c. often live in a medium hotter than their bodies, the natural temperature of which is equalized and moderated by perspiration.

If evaporation be increased by agitation of the air, the refrigeration is the greater. Hence the use of fans, ventilators, &c. which, though intended to give motion to warm air, afford likewise the virtue of cooling by facilitating and favouring evaporation.

Warm and dry air is best suited to form a refreshing current, because it is more calculated to dissolve and absorb humidity; moist air is less proper, because it is already saturated.—Hence the necessity of frequently renewing the air to preserve the coolness of our apartments.

These principles have a nearer relation to medicine than is generally supposed. We find that almost all fevers end in perspirations, which, beside the advantage of expelling the morbid matter, possess likewise that of carrying off the matter of heat, and restoring the body to its common temperature. The physician who is desirous of moderating the excess of heat in the body of a patient, ought to maintain the air in that disposition which is most suitable to his views.

The use of volatile alkali is universally acknowledged to be of advantage in burns, the tooth-ach, &c. May not these effects be attributed to the volatility of this substance, which quickly combining with heat, carries it off, and leaves an impression of cold?—Ether is a sovereign remedy for the colic. Does not its virtue depend on the same principles?

The heat which has entered into combination with bodies during their transition from the solid to the liquid state, or from this last to the aëriform state, may be again exhibited by causing these substances to return again to

the states of liquefaction or solidity. In a word, every substance which passes from the liquid to the solid state, suffers its latent heat to escape, which at this instant becomes free or thermometrical heat.

The celebrated Fahrenheit, in the year 1724, having left water exposed to a colder temperature than that of ice, the water remained fluid: but it congealed by agitation; and the thermometer, which marked several degrees beneath the freezing point, suddenly rose to that temperature. Mr. Treiwald mentions a similar fact in the Transactions; and Mr. de Ratte made the same observation at Montpellier.

Mr. Baumé has shewn in his inquiries and experiments relating to several singular phenomena exhibited by water at the instant of its congelation, that several degrees of heat are always developed at that instant.

Gaseous substances are maintained in the aëriform state merely by the heat which is combined with them; and when to these substances, thus dissolved in Caloric, another body is presented, to which they have a very strong affinity, they abandon their heat to unite with this last substance; and the caloric, thus expelled or disengaged, appears under the form of free or thermometrical heat. This disengagement of heat, by the concretion or fixation of gaseous substances, was observed by the celebrated Scheele, as may be seen in the valuable experiments which form the basis of his Treatise on Air and Fire. Since the time of this great man, rigorous calculations have been made of the quantity of latent heat existing in each of these gases: we are indebted to Messrs. Black, Crawford, Wilcke, De la Place, Lavoisier, &c. for many excellent researches on this subject.

ARTICLE II.

Concerning Light.

It appears that Light is transmitted to our eyes by a peculiar fluid which occupies the interval between us and visible bodies.

Does this fluid arrive directly from the Sun by successive emissions or radiations? or is it a peculiar fluid distributed through space, and put in action by the Sun's rotary motion, or by any other cause? I shall not enter into any discussion upon this subject, but shall confine myself to point out the phenomena.

A. The motion of light is so rapid, that it passes through nearly eighty thousand leagues in a second.

B. The elasticity of the rays of light is such that the angle of reflection is equal to the angle of incidence.

C. The fluid of light is ponderous: for if a ray of light be received through a hole in a window-shutter, and the blade of a knife be presented to it, the ray is diverted from a right line, and is inflected towards the body. This circumstance shews that it obeys the law of attraction, and sufficiently authorizes us to class it among other bodies of this nature.

D. The great Newton succeeded in decomposing the solar light into seven primitive rays, which present themselves in the following order: red, orange, yellow, green, blue, indigo, violet. Dyes present us with only three colours, which are red, blue, and yellow; the combinations and proportions of these three principles form all the shades of colour with which the arts are enriched. Philosophers have maintained that among the solar rays there are three primitive colours.—See *Les Recherches de M. Marat*.

All natural bodies may be considered as prisms which decompose or rather divide the light. Some reflect the rays without producing any change, and these are white; others absorb them all, and cause absolute blackness: the greater or less affinity of the several rays with various bodies, and perhaps likewise the disposition of the pores, is no doubt the cause that, when a pencil falls upon a body, some rays enter into combination, while others are reflected; and it is this which affords the diversity of colours, and the prodigious variety of shades under which bodies appear to our eyes.

We can no longer confine ourselves to consider light as a merely physical substance; the chemist perceives its influence in most of his operations, and finds it necessary to attend to its action, which modifies his results: and its ef-

fects are no less evident in the various phenomena of nature, than in the experiments performed in our laboratories.

We see that vegetation cannot take place without light. Plants deprived of this fluid become pale; and when in hot-houses the light comes to them from one part only, the vegetables incline towards the aperture, as if to shew the necessity of this beneficial fluid.

Without the influence of light, vegetables would exhibit but one lifeless colour; they are deprived of their beautiful shades by the interception of this luminous fluid. On these principles, celery, endive, and other plants, are bleached.

Vegetables are not only indebted to the light for their colour, but likewise for their smell, taste, combustibility, maturity, and the resinous principle, which equally depend upon this fluid. Hence it is, no doubt, that aromatic substances, resins, and volatile oils, are the inheritance of southern climates, where the light is more pure, constant, and intense.

We see, likewise, that the influence of light is evident in other beings: for, as Mr. Dorthes has observed, worms and grubs, which live in the earth or in wood, are of a whitish colour. The birds and flying insects of the night, are likewise distinguishable from those of the day by the want of brilliancy of colour; and the difference is equally marked between those of the north and of the south.

A very astonishing property of light upon the vegetable kingdom is, that when vegetables are exposed to open day-light, or to the sun's rays, they emit vital air.* We shall again attend to all these phenomena when we come to treat of the analysis of vegetables.

* This sentiment has been adopted by the chemists of all nations, but has lately been controverted by the editor of this work, who reasons in the following manner:

1st. He says, whenever oxygenous gas has been obtained from vegetables, carbonic acid, or fixed air, has been present. Upon reviewing the experiments of Dr. Priestley, he finds that this circumstance has actually taken place. The Doctor exposed plants to the influence of light, in atmospheric air, in which spirit of wine, and wax, and tallow candles, had burned out; to air which had been vitiated by the death or putrefaction of mice and fishes; and to air which had been frequently taken into his lungs, and found that the purity of the

The fine experiments of Scheele and Berthollet have shewn that the absence or presence of light has an asto-

air, was in every instance restored. (Priestley on air. Vol. iii. p. 247 to 349.)

In all these cases, carbonic acid (which is composed of carbon and oxygen) was formed; the vegetable devoured its coal for food, by which means its oxygen escaped in the form of pure air.

2dly. The seeds of *Zea* maize or Indian corn, of *apium petroselinum* or parsley, of *lactuca sativa* or lettuce, of *cucurbita citrullus* or the water melon, of *phaseolus sativus* or beans, and of *raphanus sativus* or radishes, were planted in earth, and made to vegetate in atmospheric air, confined over water in vessels of white glass, and exposed to the action of solar light. This air, when examined at various times, was found to be reduced in purity; and when its oxygenous portion was, completely absorbed, the plants died. Its oxygen united to the coal of the cotyledons of the seeds, or to that of some animal or vegetable matter contained in the earth in which they were planted, or to that of some decayed portion of the leaves, and formed carbonic acid quicker than the living plant could decompose it. To these experiments we may add, that the celebrated and accurate Scheele observed, that beans growing in atmospheric air always rendered it impure.

3dly. Young plants of *datura stramonium* or Jameston weed, of *phytolacca decandra* or the poke, of *Zea* maize or Indian corn, &c. growing in earth, were exposed to solar light in from forty to eighty ounce measures of atmospheric air, which was examined at various times, from one hour to thirty days after the plants had been placed in it. Carbonic acid gas was generally formed, and whenever this circumstance happened, the purity of the air was diminished.

When a plant in perfect health, growing in a soil which contains little vegetable or animal matter, is confined in atmospheric air, it will live a long time without producing any change in it. Many of the vegetables, which were the subjects of these experiments, did not affect the air in five days; some diminished its purity in three hours, and others altered it in a most slow and gradual manner, causing little change in it in 20 days.

4thly. Many of the same kind of vegetables were also confined in forty ounce measures of oxygenous gas, which had been well washed in lime water, and the purity of this air was very generally lessened, carbonic acid being formed.

5thly. A small handful of the healthy leaves of a variety of plants, containing no decayed parts, were exposed during four, six, and eight hours to the influence of the light of the sun, in atmospheric air confined by water, and its purity was found to be neither increased nor diminished.

6thly. The leaves of various vegetables gathered promiscuously, exposed in the same manner, generally diminished the purity of atmospheric air several degrees.

7thly. A handful of the leaves of several hundred different plants, among which may be mentioned those of the apple, pear, peach, pop-

nishing effect upon the result of chemical experiments. Light disengages vital air from several fluids, such as the

lar, fringe, and persimmon trees, were separately exposed during several hours in glass vessels to solar light, in forty ounce measures of pump water, and from five to nineteen dram measures of oxygen air were produced in each vessel. Upon analyzing the water, it was found to contain carbonic acid, with which it had been impregnated from a necessary, which stood within a yard of the pump.

8thly. The leaves of thirteen different plants were separately exposed in the usual manner, in forty ounce measures of the water of the river Schuylkill, and about ten dram measures of air were procured, the principal part of which was azotic gas, which was disengaged from the water. No carbonic acid could be detected in the water of this river.

There are three wooden bridges erected over the Schuylkill, which rest upon large wooden logs, upon which great quantities of a species of conferva grow, and which is covered by the water. Upon viewing this vegetable when the sun shone upon it, for several hours, at different times, for several years, no air could be seen to form upon it, or to rise through the water.

9thly. The leaves of the same vegetables were exposed to light, in the same manner, in the same river water, impregnated with four quarts of the water, saturated with carbonic acid, from the carbonate of lime and the sulphuric acid; and seventy-seven dram measures of oxygenous air of a very high degree of purity were obtained.

10thly. No oxygenous air could be procured by exposing vegetable leaves in boiled, distilled, rain or lime water; a proof that they do not decompose water.

11thly. Atmospheric air was impregnated with carbonic acid gas, and an handful of the leaves of nine different vegetables, were separately exposed in it, to light, seven hours. The fixed air disappeared, and the atmospheric air was greatly increased in purity.

12thly. The limbs of trees covered with healthy leaves, and some vigorous evergreens growing in their natural soil, were confined from one day to a month, in atmospheric air over water, and exposed to light, and its purity was never found to be increased, but was generally considerably diminished.

These experiments incontestibly prove, that whenever oxygen gas has been obtained from vegetables, by exposing them to the influence of solar light, carbonic acid has been present, and that it is from the decomposition of this gas, that the pure air is obtained.

As it is acknowledged that the leaves of plants separate the oxygen from carbonic acid, it may be said, that the oxygenous portion of atmospheric air is supplied by the decomposition of this gas, as it is always found in the atmosphere. The quantity of carbonic acid, accidentally diffused, in atmospheric air, (for it is not one of its component parts) is reckoned to be about one part in an hundred. It must, however, vary in different places. We would expect to find the most of it in cities, where it is formed by combustion, respiration, fermentation, and putrefaction. If one measure of the air of any great city

nitric acid, the oxygenated marine acid, &c. It reduces the oxides or calces of gold, silver, &c. It changes the nature of oxygenated muriates, according to the observations of Mr. Berthollet. Light likewise determines the phenomena of vegetation exhibited by saline solutions, as I have shewn. From all which circumstances it is evident that we ought to attend to the effect of this agent in almost all our operations.

“Organization, sensation, spontaneous motion, and life, exist only at the surface of the earth, and in places exposed to light: we might affirm that the flame of Prometheus’s torch was the expression of a philosophical truth which did not escape the ancients. Without light, nature was lifeless, inanimate, and dead: a benevolent God, by producing light, has spread organization, sensation, and thought over the surface of the earth.”—*Elementary Treatise of Chemistry* by Mr. Lavoisier.

We ought not to confound the solar light with the light of our furnaces; the light of these has, as I am convinced, very evident effects in certain phenomena: but these effects are slow, and scarcely comparable with those of the solar light.

Although heat often accompanies light, the phenomena we have mentioned cannot be attributed to mere heat. Heat may indeed modify them where it exists, but most assuredly it cannot produce them.

be passed up over lime water, in an eudiometer, no carbonate of lime will be formed, so that the quantity of carbonic acid in this air, must be extremely small. As this gas is also seized upon by alkalis, earths and metals, and absorbed by water. the proportion of it in the atmosphere may be less than one part in ten thousand.

When we consider likewise, that the oxygen is never separated from the carbonic acid by leaves. but when they are exposed in contact with it to the light of the sun, and that every perforation made in a living leaf, however minute by an insect, causes the part to decay, and absorb oxygen by day and by night; and that in the autumn, in some countries, all leaves fall on the ground, ferment and putrefy, and thus diminish the purity of common air; and that the petals and fruit of vegetables have the same effect, we must pronounce that the oxygenous portion of atmospheric air cannot be supplied by vegetation.

Am. Ed.

CHAPTER II.

Concerning Sulphur.

WE are obliged to place Sulphur among the elements, though our predecessors pretended to have determined its constituent principles. This proceeding would appear to be retrograde, if it were not evident that the correction of mistakes is a real advancement in science.

The ancients used the word Sulphur to denote every combustile and inflammable substance. Accordingly we find, in all their writings, the expressions sulphur of metals, sulphur of animals, sulphur of vegetables, &c.

Stahl assigneth a determinate value to the denomination of Sulphur; and since the time of this celebrated chemist we have confined the name to denote a body of an orange-yellow colour, dry, brittle, capable of burning with a blue flame, and exhaling a penetrating odour during combustion: when rubbed, it becomes electric; and by a light pressure in the hand it cracks, and becomes reduced to powder.

It appears that sulphur is formed by the decomposition of vegetables and animals. It has been found on the walls of necessary-houses; and when the ditch of the Porte St. Antoine, at Paris, was cleared, a considerable quantity was mixed with the decayed remains of vegetable and animal substances that had filled the ancient ditches, and there putrefied.

Mr. Deyeux has likewise proved, that sulphur exists naturally in certain plants, such as patientia, cochlearia, &c. His processes for extracting it consist in—1. The washed root must be reduced by rasping into a fine pulp; this must be washed in cold water, and passed through a sieve or cloth of an open texture: the fluid passes in a turbid state, and deposits a precipitate, which when dried proves the existence of sulphur. 2. The pulp may be

boiled, and the scum afforded by the ebullition afterwards dried: this scum contains sulphur. Several species of rumex, confounded under the name of Patience, do not contain sulphur. I have obtained it from the rumex patientia L, which grows on the mountains Cevennes, and is the same which is used at Paris. M. Le Veillard obtained sulphur by suffering vegetable substances to putrefy in well-water. Sulphur is abundantly contained in coal mines; it is found in combination with certain metals; it appears almost always where vegetable decomposition takes place; it forms the greater part of those pyritous and bituminous schisti which occupy the focus of volcanos; it is sublimed in those places where the pyrites are decomposed; it is thrown out by subterraneous fires; and is found in greater or less quantities in volcanic districts. Much has been said concerning showers of sulphur; but it is at present well known that this error has chiefly arisen from the powder of the stamina of the pine, which is carried to great distances. Henckel saw the surface of a marsh entirely covered with this powder*.

The known processes for extracting sulphur in the large way, and applying it to the purposes of commerce, consist in disengaging it from the pyrites or sulphures of copper, or of iron, by methods possessing various degrees of simplicity and economy. On this subject, the Pyritology of Henckel, Macquer's Chemical Dictionary, and the Metallurgical Tracts of Mr. Jars, may be consulted.

In Saxony and Bohemia the ores of sulphur are distilled in earthen tubes disposed in a gallery. The sulphur which is disengaged by the heat passes into receivers placed without, and in which care is taken to keep a sufficient quantity of water.

* Sulphur is found at Farmington, Ontario county, state of New-York. A stream large enough to turn a mill, rises from the bowels of the earth, and emits sulphurated hydrogen gas. The hydrogen coming in contact with the oxygen of the atmospheric air, forms water, and deposits the sulphur on the surface of the earth. The soil at this place rests upon a lime-stone rock, which in some places is sixty, and in others but a few feet deep. The temperature of the water is 50° of Fahrenheit's thermometer.

Sulphur in fine powder is also met with, adhering to the sides of the large rocks, at the Falls of Niagara, and rises from sulphurated hydrogen gas.—*Am. Ed.*

At Rammelsburg, at St. Bel, &c. large heaps of pyrites are made, which are decomposed by a gentle heat, at first applied to the mass from a stratum of combustible matter upon which it is placed. The heat is afterwards kept up by the action of the pyrites amongst each other. The sulphur which exhales cannot escape laterally, because care is taken to cover the sides with earth. It therefore rises to the summit of the truncated pyramid, where it is collected in small cavities made for that purpose. The heat of this part is sufficient to keep the sulphur in a fluid state; and it is taken out from time to time with ladles.

Almost all the sulphur used in France comes from the Solfatara. This volcanic country every where exhibits marks of the agency of subterraneous fire. The enormous masses of pyrites which are decomposed in the bowels of the earth produce heat, which sublimes part of the sulphur through apertures which the fire, and the effort of the vapours, have opened in all parts. The earths and stones which contain sulphur are distilled; and it is the result of this distillation which is called *Crude Sulphur*.

The crude sulphur is transported into France by the way of Marseilles, where it receives the necessary preparations to render it suitable to various purposes. 1. It is reduced into sticks or rolls, by fusing it, and pouring it into moulds: or, 2. It is formed into flowers of brimstone by subliming it with a gentle heat, and collecting this sulphureous vapour in a very close chamber of considerable extent. This very pure and finely divided sulphur is distinguished by the name of *Flowers of Brimstone*, or *Sublimed Sulphur*.

Sulphur enters into fusion by a moderate heat, and if the moment be seized in which the surface congeals, and the liquid sulphur contained beneath that surface be then poured out, the internal cavity will exhibit long needle-formed crystals of an octahedral figure. This process, contrived by the famous Rouelle, has been applied to the crystallization of almost all the metals. Sulphur is found naturally crystallized in Italy, at Conilla near Cadiz, &c. Its usual form is octahedral; but I have, nevertheless, seen crystals of sulphur in perfect rhomboids.

Stahl thought that he had proved, by analysis and synthesis, that sulphur is formed by the combination of his

phlogiston with the sulphuric acid. The happy series of proofs which he has left behind him for the establishment of his opinion, has appeared so complete, that, since the time of this great man, his doctrine has constantly been admitted as founded on absolute proof. This example was even urged as an instance to shew how high a degree of evidence the chemical analysis was capable of affording. But our discoveries respecting gaseous substances have shewn us, that the ancients were necessarily led into error for want of that knowledge. The immense researches of the moderns into the composition of acids have shewn that these substances are decomposed in a variety of operations; and this revolution in the state of our knowledge must have produced a similar change in our methods of explaining the phenomena. An examination of the principal experiments of Stahl, upon which his doctrine essentially depends, will sufficiently shew the truth of what we have asserted.

If one third part of charcoal, and two-thirds of sulphate of pot-ash, or vitriolated tartar, be mixed and fused in a crucible, the product is (liver of sulphur) sulphure of pot-ash. If this sulphur be dissolved in water, and the alkali be engaged by adding a few drops of sulphuric acid, a precipitate is afforded, which consists of true sulphur: "whence," says Stahl, "the sulphur is a combination of phlogiston, or the inflammable principle of the charcoal with the sulphuric acid." The experiment was true, but the consequence is absurd; because it would follow that the sulphuric acid which was added, must have possessed the property of displacing sulphuric acid united to the alkali.

If Stahl had more strictly analyzed the result or product of this operation, he would have been convinced that it does not contain a particle of sulphuric acid.

If he had been possessed of the power of operating in closed vessels, and of collecting the gaseous substances which are disengaged, he would have obtained a large quantity of carbonic acid, which arises from the combination of the oxigene of the sulphuric acid with the charcoal.

If he had exposed his liver of sulphur to the air in closed vessels, he would have seen that the vital air is ab-

sorbed, that the sulphure is decomposed, and that the sulphate of pot-ash, or vitriolated tartar is formed: which proves the re-composition of the sulphuric acid.

If charcoal be moistened with sulphuric acid or oil of vitriol, and then exposed to distillation, the products are carbonic acid or fixed air, sulphur, and much sulphureous or volatile yitriolic acid.

The experiments of Stahl exhibit the most perfect demonstration of the decomposition of the sulphuric acid into sulphur and oxigene; and it is not necessary, in the explanation of them, either to suppose the existence of an imaginary being, or to suppose that sulphur is a compounded body.

CHAPTER III.

*Concerning Carbone, or Diamond.**

PURE charcoal is called Carbone in the new Nomenclature. This substance is placed among simple bodies, because no experiment has hitherto shewn the possibility of decomposing it.

Carbone exists ready formed in vegetables. It may be cleared of all the volatile and oily principles by distillation; and, by subsequent washing in pure water, it may be deprived of all the salts which are mixed and confounded with it.

When it is required to procure carbone in a state of great purity, it must be dried by strong ignition in a closed vessel: this precaution is necessary: for the last portions

* The diamond is nothing but charcoal in a crystallized state. If the focus of a large burning lens is thrown upon diamond powder, confined in oxigen gas, the air disappears, and carbonic acid gas is formed.—*Am. Ad.*

of water adhere with such avidity, that they are decomposed, and afford oxide of carbone.*

Carbone exists likewise in the animal kingdom; it may be extracted by a process similar to that which we have described; but its quantity is small. It appears in the form of a light spongy mass, difficultly consumed in the air, and mixed with a great quantity of phosphates, and even of soda.

Carbone is likewise found in plumbago, of which it is one of the principles †.

We shall treat more fully of this substance in the analysis of vegetables. But these concise ideas are sufficient to enable us to proceed in our account of its combinations, which is indeed the only object of the present short enumeration of its properties.

* When charcoal is exposed to a red heat, in an earthen retort, it yields carbonic acid gas, and oxide of carbone. Four ounces of it taken promiscuously from a heap, gave six hundred and twenty-two ounce measures of these airs.

The 1st 10 ounce measures was the air of the vessel.			
2d	4 contained 50 parts carbonic acid gas and 70 oxide of carbone.		
3d	4 contained	20	80
4th	4	15	85
5th	360	10	90
6th	70	2	98
7th	170	0	100

622—*Am. Ed.*

† Charcoal is unalterable and indestructible by age. The beams of the theatre at Herculaneum were converted into charcoal by the lava that overflowed that city; and during the lapse of seventeen hundred years, the charcoal has remained as entire as if it had been formed but yesterday, and it will probably continue so to the end of the world. The incorruptibility of charcoal was known in the most ancient times; the famous temple at Ephesus was built upon wooden piles, which had been charred upon the outside to preserve them. Watson's Chemical Essays.—*Am. Ed.*

SECTION V.

Concerning Gases, or the Solution of certain Principles in Caloric, at the Temperature of the Atmosphere.

CALORIC, in its combination with bodies, volatilizes some of them, and reduces them to the aëriform state. The permanence in this state in the temperature of the atmosphere constitutes the gases; so that, to reduce a substance to the state of gas, consists in dissolving it in caloric.

Caloric combines with various bodies, with greater or less facility; and we are acquainted with several that, at the temperature of the atmosphere, are constantly in the state of gas: there are others which pass to this state at some degrees higher, and these are called Volatile or Evaporable substances. They differ from fixed substances, because these last are not volatilized but by the application and combination of a strong dose of caloric.

It appears that all bodies do not indiscriminately require the same quantity of caloric to assume the gaseous state; and we shall see that this proportion may be deduced from the fixation and concretion of these gaseous substances.

To reduce any substance to the state of gas, the application of caloric may be made in various manners.

The more simple method consists in placing the body in contact with another body which is heated. In this situation, the heat on one hand diminishes the affinity of aggregation or composition, by separating the constituent principles to a greater distance from each other; on the other hand, the heat unites to the principles with which it has the strongest affinity, and volatilizes them. This process is according to the method of simple affinities; for it in fact consists of the exhibition of a third body, which, presented to a compound of several principles, combines with one of them, and carries it off.

The method of double affinity may likewise be used to convert any substance into the gaseous form; and this is what happens when we cause one body to act upon another to produce a combination, in which a disengagement of some gaseous principles take place. If I pour, for example, the sulphuric acid upon the oxide of manganese, the acid combines with the metal, while its caloric seizes the oxigene, and rises with it. This principle takes place not only in this instance, but on all other occasions wherein, an operation being performed without the application of heat, there is a production of vapour or gas.

The various states under which bodies present themselves to our eyes, depend almost entirely upon the different degrees of combination of caloric with those same bodies. Fluids do not differ from solids, but because they constantly possess, at the temperature of the atmosphere, the dose of caloric which is requisite to maintain them in that state; they congeal and pass to the concrete state with greater or less facility, accordingly as the requisite quantity of caloric is more or less considerable.

All solid bodies are capable of passing to the gaseous state; and the only difference which exists between them in this respect is, that a dose of caloric is required for this purpose, which is governed—1. By the affinity of aggregation, which connects their principles, retains them, and opposes itself to a new combination. 2. By the weight of the constituent parts, which renders their volatilization more or less difficult. 3. By the agreement and attraction between the caloric and the solid body, which is more or less strong.

All bodies, whether solid or liquid, when they come to be volatilized by heat, appear in two states—that of vapour, or that of gas.

In the first case, these substances lose, in a short time, the caloric which raised them, and again appear in their original form the moment the caloric finds colder bodies to combine with; but it is rare that bodies thus divided resume their original consistence. This first state is that of vapour.

In the second case, the combination of caloric with the volatilized substance is such, that the ordinary tempera-

ture of the atmosphere is insufficient to overcome this union. This state constitutes the gases.

When the combination of caloric with any substance is such that a gas is produced, these invisible substances may be managed at pleasure, by the assistance of apparatus appropriated within our time to these uses. These apparatus are known by the name of Pneumato-chemic, Hydro-pneumatic apparatus, &c.

The pneumato-chemical apparatus, in general, consists of a wooden vessel, usually of a square form, and lined with lead or tin: two or three inches beneath the upper edge there is formed a groove, in which a wooden plank slides, having a hole in the middle, and a notch in one of its sides; the hole is made in the centre of an excavation made in the shelf, of the figure of a funnel.*

This vessel is filled with water or mercury, according to the nature of the gases operated upon. There are some which easily combine with water, and therefore require to be received over mercury.

The gases may be extracted in various manners.

When they are disengaged by fire, a recurved tube † is adapted to the neck of the retort, one extremity of which is plunged in the water or the mercury of the pneumato-chemical vessel, and opens beneath the aperture in the shelf, which is in the form of a funnel. The junction of the tube with the neck of the retort is secured with the usual lute; a vessel filled with the liquid of the cistern is inverted upon the shelf over the aperture. When the gas is disengaged from the materials in the retort, it appears in the form of bubbles, which rise, and gain the superior part of the inverted vessel. When all the water is displaced, and the bottle is full of gas, it is withdrawn, by adapting a glass plate‡ to its orifice to prevent its dissipation: it may then be poured from one vessel to another, and subjected to a variety of experiments to ascertain its nature.

* The best pneumato-chemical apparatus is made of a small cedar tub, without any lining. Vide plate ii. fig. 1.—*Am. Ed.*

† There is no occasion for a recurved tube. The neck of the retort should enter under the shelf of the hydro-pneumatic tub.—*Am. Ed.*

‡ Queen's-ware saucers or soup-plates, are preferable to glass.—*Am. Ed.*

When the gases are disengaged by means of acids, the mixture which is designed to afford them is put into a bottle with a recurved tube fitted to its neck; and this tube is plunged in the cistern in such a manner, that the bubbles of gas may pass, as in the former experiment, through the aperture of the funnel in the shelf.

The processes at present used to extract the gases, and to analyze them, are simple and commodious: and these processes have singularly contributed to our acquisition of the knowledge of these aëriform substances, whose discovery has produced a revolution in chemistry.

CHAPTER I.

Concerning Hydrogenous Gas, or Inflammable Air.

INFLAMMABLE Air is one of the constituent parts of water; a circumstance which has entitled it to the denomination of Hydrogenous Gas. Its property of burning with vital air, has caused it to be distinguished by the name of Inflammable Air.

Hydrogenous gas has been procured long since. The famous philosophical candle attests the antiquity of this discovery; and the celebrated Hales obtained from most vegetables an air which took fire.

Hydrogenous gas may be extracted from all bodies in which it is a constituent part; but the purest is that afforded by the decomposition of water, and it is this fluid which usually affords it in our laboratories. For this purpose the sulphuric acid is poured upon iron, or zinc; the water, which serves as a vehicle for the acid, is decomposed on the metal; its oxigene combines with it, while the hydrogenous gas escapes. This explanation, however contrary to the ancient notion, is not the less a demonstrated truth; in fact, the metal exists in the state of an oxide in its solution by the sulphuric acid, as may be proved by precipitating it with pure vegetable alkali: on the other

hand, the acid itself is not all decomposed; so that the oxygenous gas cannot have been afforded to the iron but by the water. Water may be decomposed likewise still more directly by throwing it upon iron strongly heated; and hydrogenous gas may be obtained by causing water to pass through a tube of iron ignited to whiteness.*

The hydrogenous gas may be extracted by the simple distillation of vegetables. Vegetable fermentation, and animal putrefaction, likewise produce this gaseous substance.†

The properties of this gas are as follow:

A. Hydrogenous gas has a disagreeable, stinking odour. Mr. Kirwan has observed, that when it is extracted over mercury, it has scarcely any smell. It contains half its weight of water, and loses its smell the moment it is deprived of this additional substance.

Kirwan has likewise observed, that the volume of hydrogenous gas is one-eighth larger when received over water than when received over mercury.

These observations appear to prove, that the offensive smell of this gas arises only from the water it holds in solution.

B. Hydrogenous gas is not proper for respiration. The abbé Fontana assures us that he could not take more than three inspirations of this air: the count Morozzo has proved that animals perish in it in a quarter of a minute. On the other hand, several northern chemists have affirmed, in consequence of experiments made on themselves,

* When the sulphuric acid diluted with water is poured upon zinc, the oxygen of the water unites to the zinc and forms an oxide of zinc; this oxide is dissolved by the sulphuric acid, and sulphate of zinc or white vitriol is formed; the hydrogen of the water escapes in the form of inflammable air. One ounce of iron or zinc will yield three hundred and sixty-five ounce measures of hydrogenous gas.

The best mode of procuring inflammable air, is to fill an eight ounce vial half full of small iron tacks, and cover them with water. Then pour over them gradually about one ounce measure of the sulphuric acid, and adapt a bent glass, tin or copper tube, entering a perforated cork, to the mouth of the vial. Vide plate ii. fig. 5.—*Am. Ed.*

† This is a mistake. The gases obtained by vegetable fermentation or distillation, are carbonic acid gas, carbonated hydrogen gas, and oxide of carbon.—*Am. Ed.*

that hydrogenous gas might be respired without danger; and it is some years since the unfortunate Pilatre du Rozier filled his lungs with it at Paris, and set it on fire during the expiration, which forms a very curious jet of flame. It was remarked to him, that the abbé Fontana had objected against the accuracy of the Swedish chemists. This intrepid philosopher answered the objection by mixing one-ninth of atmospherical air with very pure hydrogenous gas. He respired this mixture, as usual; but when he attempted to set it on fire, the consequence was an explosion so dreadful, that he imagined all his teeth were blown out.

This opposition of opinions, and contradiction of experiments, respecting a phenomenon which seems capable of unanswerable decision by one single experiment, induced me to have recourse to trial, to fix my own ideas on the subject.

Birds, successively placed in a vessel of hydrogenous gas, died, without producing the smallest perceptible change in the gas itself.

Frogs placed in forty inches of hydrogenous gas died in the space of three hours and a half; while others lived fifty-five hours in oxygenous gas and atmospheric air; and when I took them out still living, the air was neither vitiated nor diminished. Numerous experiments which I have made upon these animals, have led me to observe that they have the faculty of stopping their respiration, when placed in any noxious gas, to such a degree, that they inspire only once or twice, and afterwards suspend every function on the part of the respiratory organ.

I have since had occasion to observe that these animals are not reduced into a putrid mass by remaining in hydrogenous gas, as was affirmed some time ago. The fact which may have imposed on chemists who related this circumstance, is, that frogs are often enveloped in a mucus or sanies, which appears to cover them; but they exhibit the same phenomenon in all the gases.

After having tried the hydrogenous gas upon animals, I determined to respire it myself; and I found that the same volume of this air might be several times respired without danger. But I observed that this gas was not changed by these operations; whence I concluded that it

is not respirable: for, if it were, it would suffer a change in the lungs, the object of respiration not being confined to the reception and emission of a fluid merely; it is a function much more noble, more interesting, more intimately connected with the animal economy: and we ought to consider the lungs as an organ which is nourished by the air, digests that which is presented to it, retains the beneficial, and rejects the noxious part. Since, therefore, inflammable air can be respired several successive times without danger to the individual, and without any alteration or change in itself, we may conclude indeed that inflammable air is not a poison, but that it cannot be considered as an air essentially proper to respiration. It is with hydrogenous gas in the lungs, as with those balls of moss and resin which certain animals swallow during the rigorous season of the winter. These balls are not digested, since the animals void them at the return of spring: but they delude hunger; and the membranes of the stomach are exercised upon them without danger, in the same manner as the lungs exert themselves upon the hydrogenous gas presented to them.

C. Hydrogenous gas is not combustile alone; it does not burn but by the concurrence of oxigene. If a vessel filled with this gas be reversed, and a lighted taper be presented to it, the hydrogenous gas is found to burn at the surface of the vessel; but the candle is extinguished the moment it is plunged lower. The most inflammable bodies, such as phosphorus, do not burn in an atmosphere of hydrogenous gas.

D. Hydrogenous gas is lighter than common air. One cubic foot of atmospheric air weighs seven hundred and twenty grains; a cubic foot of hydrogenous gas weighs seventy-two grains. The barometer being at 29' 9, and the thermometer 60° Fahrenheit, Mr. Kirwan found the weight of this air to that of common air as eighty-four to one thousand; consequently it was about twelve times as light.

Its specific gravity varies very much, because it is difficult to obtain it constantly of the same degree of purity. That which is extracted from vegetables contains the carbonic acid and oil, which increases its weight.

This levity of hydrogenous gas has caused certain philosophers to presume that it ought to arrive at and occupy the superior part of our atmosphere; and upon this supposition the most brilliant conjectures have been made respecting the influence which a stratum of this gas, predominating over the rest of the atmosphere, ought to produce in meteorology. They were not aware that this continual loss of matter is not agreeable to the wise economy of nature. They did not observe that this gas, during its ascent in the air, combines with other bodies, more especially the oxigene, and that water and other products are the result; the knowledge of which must necessarily lead us to that of most meteors.

The theory of balloons, or aërostatic machines, is founded on this levity of the hydrogenous gas.

In order that a balloon may rise in the atmosphere, it is sufficient that the weight of the balloon itself, and the air it encloses, should be less considerable than that of an equal bulk of atmospheric air; and it must rise till its weight is in equilibrio with an equal volume of the surrounding air.

The theory of the Mongolfiers is very different from this. In this case a given volume of atmospheric air is rarefied by heat, and kept separated from the common mass by a hollow vessel of cloth. This rarefied space may therefore be considered for a moment as consisting of a mass of air of greater levity, which must necessarily make an effort to rise in the atmosphere, and carry its covering along with it.

E. Hydrogenous gas exhibits various characters, according to its degree of purity, and the nature of the substances which are mixed with it.

It seldom happens that this gas is pure. That which is afforded by vegetables contains oil, and the carbonic acid. The inflammable air of marshes is mixed with a greater or less quantity of carbonic acid; and that which is afforded by the decomposition of pyrites sometimes holds sulphur in solution.

The colour of hydrogen, when set on fire, varies according to its mixtures. One-third of the air of the lungs, mixed with the inflammable air of pit-coal, affords a flame of a blue colour; inflammable air, mixed with nitrous air,

affords a green colour; the vapour of ether affords a white flame. The various mixtures of these gases, and the degree of compression to which they are subjected, when expressed out of an aperture in order to burn them, have, in the hands of certain operators, afforded very agreeable illuminations, well deserving the attention of learned and curious observers.

F. Hydrogenous gas possesses the property of dissolving sulphur. In this case it contracts a stinking smell, and forms hepatic gas.

Mr. Gengembre put sulphur into inverted vessels filled with hydrogenous gas, and dissolved it by means of the burning-glass. The hydrogenous gas, by this treatment, obtained all the characteristic properties of hepatic gas.

The formation of this gas is almost always an effect of the decomposition of water. In fact, the alkaline sulphures, or livers of sulphur, do not emit any disagreeable smell while they are dry; but the moment they are moistened, an abominable smell is perceived, and sulphate of potash, or vitriolated tartar, begins to be formed. These phenomena prove that the water is decomposed; that one of its principles unites to the sulphur, and volatilizes it; while the other combines with the alkali, and forms a more fixed product.

Sulphurated hydrogenous gas may be obtained by dissolving the sulphures or hepars by acids. Those acids in which the oxigene is most adherent disengage the greatest quantity. The muriatic acid produces twice as much as the sulphuric. That which is produced by this last, burns with a blue flame; but that which is disengaged by the muriatic acid, burns with a yellowish white flame.

Scheele has taught us the means of obtaining this gas in great abundance, by decomposing artificial pyrites, formed by three parts of iron and one of sulphur, to which spirit of vitriol is added.

The natural decomposition of pyrites in the bowels of the earth produces this gas; which escapes with certain waters, and communicates peculiar virtues to them.

The most general properties of these gases are:

1. They render the white metals black.
2. They are improper for respiration.
3. They impart a green colour to most blue vegetable substances.

4. They burn with a light blue flame, and deposite sulphur by this combustion.

5. They mix with the oxygenous gas of the atmospheric air, and form water; at the same time that the sulphur, before held in solution, falls down. Hence it happens that sulphur is found in the channels of hepatic waters, though their analysis does not shew the existence of an atom of that substance held in solution.

6. They impregnate water, and are sparingly soluble in that fluid; but heat or agitation dissipates them again.

The air which burns at the surface of certain springs, and forms what is known by the name of burning springs, consists of hydrogenous gas holding phosphorus in solution. It smells like putrid fish. The Pere Lampi has discovered one of these springs in the isles of St. Colombat. Dauphiny exhibits another similar spring at the distance of four leagues from Grenoble. The *ignes fatui* which glide along burying-grounds, and which the superstitious people suppose to consist of the spirits of the departed, are phenomena of this nature, which we shall speak of when we come to treat of phosphorus.

CHAPTER II.

Concerning Oxygenous Gas, or Vital Air.

THIS gaseous substance was discovered by the celebrated Priestley, on the 1st of August, 1774. Since that memorable day, means have been devised of obtaining it from various substances; and its properties have shewn that it is a production of the most interesting nature in the knowledge of chemistry.

No part of the atmosphere exhibits vital air in its greatest degree of purity. It is always combined, mixed, or altered by other substances.

But this air, which is the most general agent in the operations of nature, exists in combination with various substances; and it is by their decomposition that it may be extracted and procured.

A metal exposed to the air becomes changed; and these changes are produced only by the combination of the pure air with the metal itself. Simple distillation of some of these metals thus changed, or oxides, is sufficient to disengage this vital air; and it is then obtained in a very pure state, by receiving it in the hydro-pneumatic apparatus. One ounce of red precipitate affords about a pint.

All acids have vital air for their base; there are some which yield it easily. The distillation of nitre decomposes the nitric acid; and about twelve hundred cubic inches of oxygenous gas are obtained from a pound of this salt.*

The nitric acid, when distilled from various substances, is decomposed, and its constituent parts may be obtained separately.

Messrs. Priestley, Ingenhousz, and Sennebier discovered nearly at the same time that vegetables exposed to the light of the sun emit vital air. We shall elsewhere speak of the circumstances of these phenomena; but shall at present confine ourselves to the observation, that the emission of vital air is proportioned to the vigour of the plant, and the vivacity of the light; and that the direct emission of the rays of the sun is not necessary to produce this gaseous dew; it is sufficient that the plant be well enlightened, in order that it may transpire pure air: for I have often collected it in abundance from a kind of moss which covers the bottom of a vessel filled with water, and so well defended, that the sun never shone directly upon it.

In order to procure the vital air which is disengaged from plants, it is sufficient to enclose them beneath a glass vessel filled with water, and inverted over a tub filled with the same fluid. The moment the plant is acted on by the sun, small bubbles of air are formed on its leaves, which

* The air obtained from nitre is so contaminated with azotic gas, one of the component parts of the nitric acid, that it hardly deserves the name of pure air.—*Am. Ed.*

detaching themselves, rise to the upper part of the vessel, and displace the liquid.

This dew of vital air is a beneficial gift of nature, to repair incessantly the consumption of vital air. The plant absorbs atmospherical mephitic, and emits vital air. Man, on the contrary, is kept alive by vital air, and emits much mephitic. It appears therefore that the animal and vegetable kingdoms labour for each other; and that by this admirable reciprocity of service the atmosphere is continually repaired, and an equilibrium maintained between its constituent principles.

The influence of solar light is not confined to the production of vital air by its action upon vegetables alone; it has likewise the singular property of decomposing certain substances, and disengaging this gas.*

A bottle of oxygenated muriatic acid, exposed to the sun, suffers all the superabundant oxygen which it contained to escape, and passes to the state of ordinary muriatic acid. The same acid, exposed to the sun in a bottle wrapped in black paper, does not suffer any change; and, when heated in a dark place, is even reducible into gas without decomposition. The nitric acid likewise affords oxygenous gas, when exposed to the sun; whereas heat alone volatilizes it without decomposition.

The muriate, or marine salt of silver, placed under water, and exposed to the sun, suffers oxygenous gas to escape from it. I have observed that red precipitate likewise affords oxygen in similar cases, and that it becomes black in no very long space of time.

We may likewise obtain oxygenous gas by disengaging it from its bases by means of the sulphuric acid. The process to which I give the preference, on account of its simplicity, is the following:—I take a small apothecary's phial, into which I put one or two ounces of manganese, and pour thereon a sufficient quantity of sulphuric acid to form a liquid paste. I afterwards fit a cork to the opening of the bottle, with a hole through it, into which is inserted a recurved tube; one of whose extremities enters the bottle, while the other is placed under the shelf of the

* Vide what has been said in note p. 100.—*Am. Ed.*

pneumato-chemical apparatus. When the apparatus is thus disposed, I present a small coal to the lower part of the bottle, and oxygenous gas is immediately disengaged.

The manganese I use was discovered by me at St. Jean de Gardonnenque. It affords its oxygen with such facility, that nothing more is necessary for this purpose than to incorporate it with the sulphuric acid. This gas is not perceptibly mixed with nitrogenous gas (or phlogisticated air); and the first bubble is as pure as the last. *

Oxygenous gas exhibits certain properties, according to its degree of purity. These depend in general upon the substances which afford it. That which is obtained from the mercurial oxides almost always holds a small quantity of mercury in solution: I have been a witness to its having produced a speedy salivation on two persons who used it for disorders of the lungs. In consequence of these observations, I filled bottles with this gas, exposed them to an intense cold, and the sides became obscured with a stratum of mercurial oxide, in a state of extreme division. I have several times heated the bath, over which I caused this gas to pass; and I obtained, at two different times, a yellow precipitate in the bottle in which I had received the gas.

The oxygenous gas extracted from plants is not equally pure with that afforded by the metallic oxides:† but from whatever substances it is obtained, its general properties are the following:

A. It is more ponderous than the air of the atmosphere; the cubic foot of atmospherical air weighing seven hundred and twenty grains, while the cubic foot of pure air weighs seven hundred and sixty-five. According to Mr. Kirwan, its weight is to that of common air as eleven

* The best method of obtaining oxygenous gas, is by exposing the black oxide of manganese to a red heat in an iron matrass. When procured in this manner, it is generally contaminated with carbonic acid gas and azotic air. The carbonic acid may be separated, by washing the gases in lime water, but there is no mode of removing the azotic air.—*Am. Ed.*

† Twelve ounce measures of the oxygen air, obtained by exposing vegetable leaves to the influence of solar light, in water impregnated with carbonic acid gas, contained four ounce measures of azotic air.—*Am. Ed.*

hundred and three to one thousand. One hundred and sixteen inches of this air weighed 39,09 grains; one hundred and sixteen inches of common air weighed 35,38 grains at the temperature of ten degrees of Reaumur, and twenty-eight inches of pressure. One hundred parts of common air weighed forty-six, and one hundred parts of vital air fifty.

B. Oxygenous gas is the only fluid proper for combustion. This acknowledged truth caused the celebrated Scheele to give it the name of Air of Fire.

To proceed with greater order in the examination of one of the most important properties of oxygenous gas, since it belongs exclusively to this fluid, we shall lay down the four following principles, as incontestable results of all the known facts.

The first principle.—Combustion never takes place without vital air.

The second principle.—In every combustion there is an absorption of vital air.

The third principle.—There is an augmentation of weight in the products of combustion equal to the weight of the vital air absorbed.

The fourth principle.—In all combustion there is a disengagement of heat and light.

I. The first of these propositions is a strict truth. Hydrogenous gas does not burn alone, without the assistance of oxygen; and all combustion ceases the moment that oxygenous gas is wanting.

II. The second principle contains a truth no less general. If certain bodies, such as phosphorus, sulphur, &c. be burned in very pure oxygenous gas, this is absorbed to the last particle; and when the combustion is effected in a mixture of several gases, the oxygen alone is absorbed, and the others remain unchanged.

In the slower combustions, such as the rancidity of oils, and the oxidation of metals, there is equally an absorption of oxygen, as may be shewn by confining these bodies in a determinate mass of air.

III. The third principle, though not less true than the preceding, requires more explanation; and for this purpose we shall distinguish those combustions whose result, residue, and product are fixed, from those which afford

volatile and fugacious substances. In the first case the oxygenous gas quietly combines with the body; and by weighing the same body the moment the combustion has completely taken place, it is easily ascertained whether the increase in weight be proportioned to the oxygen absorbed. This happens in all the cases wherein the metals are oxidized, or oils rendered rancid; and in the production of certain acids, such as the phosphoric, the sulphuric, &c. In the second case, it is more difficult to weigh all the results of the combustion, and consequently to ascertain whether the augmentation in weight be proportioned to the quantity of the air absorbed. Nevertheless, if the combustion be made in inverted vessels, and the whole of the products be collected, it is found that their augmentation in weight is strictly equal to that of the air absorbed.

IV. The fourth principle is that whose applications are the most interesting to be known.

In most combustions, the oxygenous gas becomes fixed and concrete. It therefore abandons the caloric which maintained it in the æriform state; and this caloric being set at liberty, produces heat, and endeavours to combine itself with the substances nearest at hand.

The disengagement of heat is therefore a constant effect in all the cases wherein vital air is fixed in bodies; and it follows, from this principle—1. That heat is most eminently resident in the oxygenous gas which maintains combustion. 2. That the more oxygen is absorbed in a given time, the stronger will be the heat. 3. That the only method of producing a violent heat consists in burning bodies in the purest air. 4. That fire and heat must be more intense in proportion as the air is more condensed. 5. That currents of air are necessary to maintain and expedite combustion. It is upon this principle that the theory of the effects of the cylinder lamps is founded: the current of air, which is renewed through the tube, supplies fresh air every instant; and by continually applying a new quantity of oxygenous gas to the flame, a heat is produced sufficient to ignite and destroy the smoke.

It is likewise on the same principle that we explain the great difference that exists between heat produced by a

slow combustion, and that which is afforded by rapid combustion. In the latter case the same quantity of heat and light is produced in a second, which might have been produced in the other case in a much longer time.

The phenomena of combustion, by means of oxygenous gas, depend likewise upon the same laws. Professor Lichtenberger, of Gottingen, soldered the blade of a knife to a watch spring by means of oxygenous gas; Messrs. Lavoisier and Ehrmann have subjected almost all the known bodies to the action of fire maintained by oxygenous gas alone; and they produced effects which the burning glass could not have operated.

Mr. Ingenhousz has shewn us, that if an iron wire be bent into a spiral form, and any combustible substance whatever be fixed to one of its ends, and set on fire, the wire will itself be fused by plunging it into oxygenous gas.

Mr. Forster, of Gottingen, found that the light of glow-worms is so beautiful and bright in oxygenous gas, that one single insect was sufficient to afford light to read the *Annales Savantes* of Gottingen, printed in a very small character.* Nothing more is wanting therefore than to apply this air to combustion with facility and economy; and Mr. Meusnier has succeeded in this, by constructing a simple and commodious apparatus. On this subject the treatise of Mr. Ehrmann upon fusion may be consulted.

The description of the gazometer may likewise be seen in the *Elementary Treatise of Chemistry*, by Mr. Lavoisier.†

We shall distinguish three states in the very act of combustion—ignition, inflammation, and detonation.

* The fire-fly and glow worm of America produce no such effect.—*Am. Ed.*

† The highest degree of heat is produced by the flame of hydrogen gas, urged by oxygenous air.

An ingenious apparatus for this purpose, superior to any thing of the kind they have in Europe, has been invented by Mr. Robert Hare, junior, of this city. An account of it may be seen in *Tilloch's Philosophical Magazine*, and in the fifth volume of the *American Philosophical Transactions*.—*Am. Ed.*

Ignition takes place when the combustible body is not in the aëriform state, nor susceptible of assuming that state by the simple heat of combustion. This happens when well-made charcoal is burned.

When the combustible body is presented to oxygenous gas, in the form of vapour or gas, the result is flame; and the flame is more considerable, in proportion as the combustible body is more volatile. The flame of a candle is not kept up but by the volatilization of the wax, which is continually effected by the heat of the combustion.

Detonation is a speedy and rapid inflammation, which occasions a noise by the instantaneous formation of a vacuum. Most detonations are produced by the mixture of hydrogenous and oxygenous gas, as I have shewn in my Memoir upon Detonations, in the year 1781. It has been since proved, that the product of the rapid combustion of these two gases is water. Very strong detonations may be produced by burning a mixture of one part of oxygenous gas with two of hydrogen. The effect may be rendered still more terrible, by causing the mixture to pass through soap-water, and setting fire to the bubbles which are heaped on the surface of the fluid.

Chemistry presents several cases in which the detonation arises from the sudden formation of some gaseous substances, such as that which is produced by the inflammation of gunpowder; for in this case there is a sudden production of carbonic acid, of nitrogen gas, &c. The production or instantaneous creation of any gas whatever, must occasion a shock or agitation in the atmosphere, which necessarily affords an explosion; the effect of these explosions increases, and becomes stronger, from the opposition of any obstacles against the escape of the gas.

C. Oxygenous gas is the only gas proper for respiration. It is the most eminent property which has entitled it to the name of Vital Air; and we shall give the preference to this denomination in the present article.

It has long since been known that animals cannot live without the assistance of air. But the phenomena of respiration have been very imperfectly known until lately.

Of all the authors who have written concerning respiration, the ancients are those who have had the most ac-

curate ideas of it. They admitted in the air a principle proper to nourish and support life, which they denoted by the name of *pabulum vitæ*; and Hippocrates expressly says, *spiritus etiam alimentum est*. This idea, which was connected with no hypothesis, has been successively replaced by systems void of all foundation. Sometimes the air has been considered as a stimulus in the lungs, which kept up the circulation by its continual action. Vide Haller.—Sometimes the lungs have been considered as bellows designed to cool the body, heated by a thousand imaginary causes: and when it was proved that the volume of air was diminished in the lungs, it was thought to be an explanation of every difficulty, to say that the air was deprived of its spring.

At this day, however, we are enabled to throw some light on one of the most important functions of the human body. In order to proceed with more perspicuity, we shall reduce our notions to several principles.

1. No animal can live without the assistance of air. This fact is universally admitted; but it has not been known until lately that the faculty which the air possesses of answering the purpose of respiration, arises only from one of the principles of atmospheric air, known by the name of vital air.

2. All animals do not require the same purity in the air. Birds, as well as men, and the greatest part of quadrupeds, require a very pure air; but those which live in the earth, or which hide themselves in a state of stupefaction during the winter, can subsist by means of a less pure air.

3. The manner of respiring the air is different in the several subjects. In general, nature has given to animals an organ, which by its involuntary dilatation and contraction receives and expels the fluid in which the animal moves and exists. This organ is more or less perfect, more or less concealed and defended from external injury, according to its importance, and influence upon the life of the creature, as Mr. Broussonnet has observed.

Amphibious animals respire by means of lungs: but they can suspend their motion even whilst they are in the air; as I have observed with regard to frogs, which stop their respiration at pleasure.

The manner of respiration in fishes is very different; these animals come from time to time to inhale the air at the surface of the water, where they fill their vesicle, and digest it afterwards at their ease. I have for a long time observed the phenomena of fishes in the act of respiration; and am well assured that they are sensible of the action of all the gases, like other animals. Mr. De Fourcroy has observed that the air contained in the vesicle of the carp is nitrogene gas (phlogisticated air).

Insects with tracheæ exhibit organs still more remote from ours in their construction. In these animals, respiration is effected by the tracheæ distributed along the body. They accompany all the vessels, and terminate by losing themselves in insensible pores at the surface of the skin.

These insects appear to me to exhibit several very evident points of analogy with vegetables.

I. Their respiratory organs are formed in the same manner, being disposed through the whole body of the vegetable and the animal.—2. Insects do not require a great degree of purity in the air; and plants are nourished with atmospherical mephitis.*—3. Both the one and the other transpire vital air. The abbé Fontana discovered several insects in stagnant waters, which, when exposed to the sun, afforded vital air: and the green matter which is formed in stagnant waters, and is by Dr. Priestley placed among the *confervæ*, in conformity with the opinion of his friend Mr. Bewley—which Mr. Senebier has supposed to be the *conferva cespitosa filis rectis undique divergentibus Halleri*, and which has appeared to Dr. Ingenhousz to be nothing else but a mass of animalcula—affords a prodigious quantity of this air when exposed to the sun.—4. Insects likewise afford, by chemical analysis, principles similar to those of plants, such as resins, volatile oils, &c.

* This is by no means true. When a plant is made to grow in atmospheric air, it always dies when the oxigenous portion of this air disappears.—*Am. Ed.*

Father Vaniere appears to have known, and very elegantly expressed, the property of vegetables to support themselves by means of vital air:

. . . . Arbor enim (res non ignota,) ferarum
Instar et halituum, piscisque latentis in imo
Gurgite, vitales et reddit et accipit auras.

Proedium Rusticum, l. vi.

Animals with lungs respire only by virtue of the vital air which surrounds them. Any gas deprived of this mixture becomes immediately improper for respiration; and this function is exercised with so much the greater liberty, as vital air exists in a greater proportion in the air respired.

Count Morozzo placed successively several full-grown sparrows under a glass bell, inverted over water. It was at first filled with atmospherical air, and afterwards with vital air. He observed—

1. In atmospherical air,

	Hours.	Min.
The first sparrow lived	3	0
The second - - -	0	3
The third - - -	0	1

The water rose in the vessel eight lines during the life of the first; four during the life of the second; and the third produced no absorption.

2. In vital air,

	Hours.	Min.
The first sparrow lived	5	23
The second - - -	2	10
The third - - -	1	30
The fourth - - -	1	10
The fifth - - -	0	30
The sixth - - -	0	47
The seventh - - -	0	27
The eighth - - -	0	30
The ninth - - -	0	22
The tenth - - -	0	21

From these experiments it may be concluded, 1. That an animal lives longer in vital air than in atmospherical air. 2. That an animal can live in air in which another has died. 3. That, independent of the nature of the air,

respect must be had to the constitution of the animals, as the sixth lived forty-seven minutes, and the fifth only thirty. 4. That there is either an absorption of air, or the production of a new kind of air, which is absorbed by the water as it rises.

It remains, at present, to examine what are the changes produced by respiration. 1. In the air. 2. In the blood.

The gas emitted by expiration is a mixture of nitrogene gas, carbonic acid, and vital air. If the air which issues from the lungs be made to pass through lime-water, it renders it turbid; if it be received through tincture of turnsole, it reddens it; and if a pure alkali be substituted instead of the tincture of turnsol, it becomes effervescent.

When the carbonic acid has been absorbed by the foregoing process, the remainder of this air consists of nitrogene gas and vital air. The vital air is shewn to be present by means of nitrous air. The air in which I had caused five sparrows to perish, afforded seventeen hundredth parts of vital air. After having thus deprived the expired air of all its vital air, and all its carbonic acid, the remainder is nitrogene gas.

It has been observed that frugivorous animals vitiate the air less than carnivorous animals.

A portion of the air is absorbed in respiration. Borelli formerly took notice of this; and Dr. Jurin had calculated that a man inspired forty cubic inches of air in his usual inhalations, and that in the greatest he could receive two hundred and twenty inches; but that a portion was always absorbed. The celebrated Dr. Hales endeavoured to determine this absorption more strictly, and he estimated it at a sixty-eighth of the total of the respired air; but he did not consider it as more than a hundred and thirty-sixth, on account of errors which he supposed to have taken place. Now a man respire twenty times in a minute, and inhales forty cubic inches of air at each inspiration: this makes forty-eight thousand per hour; which, divided by one hundred and thirty-six, gives about three hundred and fifty-three inches of air absorbed and destroyed in the hour. The process of Hales is not exact; because he passed the air expired through water, which must have retained a sensible proportion.

From more accurate experiments, Mr. De La Metherie has proved, that three hundred and sixty cubic inches of vital air are absorbed in an hour.

My experiments have not shewn near so great a loss.

This fact affords a proof of the facility with which air is vitiated by respiration when it is not renewed, and shews why the air of theatres is in general so unwholesome.

II. The first effect which the air appears to produce upon the blood is, that of giving it a vermilion-colour. If the blackish venous blood be exposed in a pure atmosphere, it becomes of a vermilion-colour at its surface: this fact is daily observed when blood is suffered to remain exposed in a porringer to the air. Air which has remained in contact with blood extinguishes candles, and precipitates lime-water. Air injected into a determinate portion of a vein between two ligatures, renders the blood of a higher colour according to the fine experiments of Dr. Hewson.

The blood which returns from the lungs is of a higher colour, according to the observations of Messrs. Cigna, Hewson, &c. Hence arises the great intensity of the colour of arterial blood, compared with venous blood.

Mr. Thouvenel has proved, that by withdrawing the air which is in contact with the blood, it may be again made to lose its colour.

Mr. Beccaria exposed blood in a vacuum, where it remained black, but assumed the most beautiful vermilion-colour as soon as it was again exposed to the air. Mr. Cigna covered blood with oil, and it preserved its black colour.

Dr. Priestley caused the blood of a sheep to pass successively into vital air, common air, mephitic air, &c. and he found that the blackest parts assumed a red colour in respirable air, and that the intensity of this colour was in proportion to the quantity of vital air present. The same philosopher filled a bladder with blood, and exposed it to pure air. That portion of blood which touched the surface of the bladder, became red, while the internal part remained black: an absorption of air therefore took place through the bladder, in the same manner as when the contact is immediate.

All these facts incontestably prove, that the vermilion-colour assumed by the blood in the lungs, is owing to the pure air which combines with it.

The vermilion-colour of blood is therefore the first effect of the contact, absorption, and combination of pure air with the blood.

The second effect of respiration is to establish a real focus of heat in the lungs; which is a circumstance very opposite to the precarious and ridiculous notion of those who have considered the lungs as a kind of bellows designed to cool the human body.

Two celebrated physicians, Hales and Boerhaave, have observed that the blood acquired heat in passing through the lungs; and modern physiologists have estimated this augmentation of heat at eleven hundredths.

The heat in each class of individual animals is proportioned to the magnitude of their lungs, according to Messrs. De Buffon and Broussonet.

Animals with cold blood have only one auricle and one ventricle, as Aristotle observed.

Persons who have respired vital air, agree in affirming that they perceived a gentle heat vivifying the lungs, and insensibly extending from the breast into all the other parts of the body.

Ancient and modern facts unite therefore to prove, that a focus of heat really exists in the lungs, and that it is maintained and kept up by the air of respiration. We are able, at present, to explain all these phenomena. In fact there is an absorption of vital air in respiration. Respiration then may be considered as an operation by means of which vital air passes continually from the gaseous to the concrete state: it must therefore at each instant abandon the heat which held it in solution, and in the state of gas. This heat produced at every inspiration must be proportioned to the volume of the lungs, to the activity of this organ, to the purity of the air, the rapidity of the inspirations, &c. Hence it follows that, during the winter, the heat produced must be more considerable, because the air is more condensed, and exhibits more vital air under the same volume. By the same reason, respiration ought to produce more heat in the inhabitants of northern climates; and this is one of the causes

prepared by nature to temperate, and continually balance, the extreme cold of these climates. It follows likewise that the lungs of asthmatic persons are less capable of digesting the air; and I am assured that they emit the air without vitiating it: from which cause their complexion is cold, and their lungs continually languishing; vital air is therefore wonderfully comfortable to them. It may be easily conceived from these principles why the heat of animals is proportioned to the volume of their lungs; and why those which have only one auricle, and one ventricle, have cold blood, &c.

The phenomena of respiration are therefore the same as those of combustion.

Vital air, by combining with the blood, forms the carbonic acid, which may be considered as antiputrescent as long as it remains in the circulation; and that it is afterwards emitted through the pores of the skin, according to the experiments of the count De Milly, and the observations of Mr. Fouquet.

Vital air has been used with success in certain disorders of the human body. The observations of Mr. Cailens are well known. He caused persons affected with phthisical disorders to respire it with the greatest success. I have myself been a witness to the most wonderful effects of this air in a similar case. Mr. De B——— was in the last stage of a confirmed phthisis. Extreme weakness, profuse sweats, a flux of the belly, and in short every symptom announced the approach of death. One of my friends, Mr. De P——, put him on a course of vital air. The patient respired it with delight, and asked for it with all the eagerness of an infant at the breast. During the time that he respired it he felt a comfortable heat, which distributed itself through all his limbs. His strength increased with the greatest rapidity; and in six weeks he was able to take long walks. This state of health lasted for six months: but after this interval he relapsed; and being no longer able to have recourse to the use of vital air, because Mr. De P——— had departed for Paris, he died.—I am very far from being of opinion that the respiration of vital air ought to be considered as a specific, in cases of this nature. I am even in doubt whether this powerful air is perfectly adapted to such cir-

cumstances; but it inspires cheerfulness, renders the patient happy, and in desperate cases it is most certainly a precious remedy, which can spread flowers on the borders of the tomb, and prepare us in the gentlest manner for the last dreadful effort of nature.

The absolute necessity of vital air in respiration, enables us to lay down positive principles for purifying the corrupted air of any given place. This may be done in three ways. The first consists in correcting the vitiated air by means of substances which are capable of seizing the noxious principles. The second consists in displacing the corrupted air, and substituting fresh air in the room of it; as is done by means of ventilators, the agitation of doors, &c. And the third consists in pouring into the mephitised atmosphere a new quantity of vital air.

The processes employed in purifying corrupted air, are not all certain in their effects. The fires which are lighted for this purpose have no other advantage than to establish ascending currents, and to burn unhealthy exhalations; and perfumes do nothing more than disguise the bad smell, without changing the nature of the air, as the experiments of Mr. Achard shew.

CHAPTER III.

Concerning Nitrogene Gas, Azote, or Atmospheric Mephitis.

IT has been long since ascertained, that air which has served the purposes of combustion and respiration is no longer proper for those uses: the air thus corrupted, has been distinguished by the names of Phlogisticated Air, Mephitised Air, Atmospheric Mephitis, &c. I call it Nitrogene Gas, for the reasons explained in the preliminary discourse.

But this residue of combustion or respiration is always mixed with a small quantity of vital air and carbonic acid, which must be removed in order to have the nitrogene gas in a state of purity. There are several methods

which may be used to obtain nitrogene gas, in a very pure state.

1. Scheele has taught us, that by exposing sulphure of alkali, or liver of sulphur, in a vessel filled with atmospheric air, the vital air is absorbed; and, when the absorption is complete, the nitrogene gas remains pure.

By exposing, in atmospheric air over mercury, a mixture of iron filings and sulphur, kneaded together with water, Mr. Kirwan obtained nitrogene gas so pure, that it suffered no diminution by nitrous gas. He deprived it of all humidity, by successively introducing dried blotting-paper into the vessel which contained it. Care must be taken to withdraw this air in time from the paste which affords it; otherwise it will be mixed with hydrogene or inflammable gas, which is afterwards disengaged. 2. When by any means, such as the oxidation of metals, the rancidity of oils, the combustion of phosphorus, &c. the vital air of the atmosphere is absorbed, the residue is nitrogene gas. All these processes afford methods of greater or less accuracy to determine the proportions of vital air and nitrogene gas in the composition of the atmosphere.

3. This mephitic may likewise be procured by treating muscular flesh, or the well-washed fibrous part of blood, with nitric acid in the hydro-pneumatic apparatus. But it must be carefully observed that these animal matters ought to be fresh; for if they have begun to be changed by the putrid fermentation, they afford carbonic acid mixed with hydrogene gas.*

A. This gas is improper for respiration and combustion.

B. It mixes with the other airs, without combining with them.

C. It is lighter than the atmospheric air, the barometer standing at 30. 46, and Fahrenheit's thermometer at 60: the weight of nitrogene gas is to that of common air as nine hundred and eighty-five to one thousand.

D. Mixed with vital air, in the proportion of 78 to 22, it constitutes our atmosphere. The other principles which

* Azotic gas procured in this manner is generally contaminated with nitrous air.—*Am. Ed.*

analysis exhibits in the atmosphere, are only accidental, and by no means necessary.†

SECTION VI.

Concerning the Mixture of Nitrogene and Oxigene Gas ; or of Atmospheric Air.

THE gaseous substances we have treated of seldom exist alone and insulated ; nature presents them every where to our observation in a state of mixture or of combination. In the first case these gases preserve the aëriform state ; in the second they for the most part form fixed and solid bodies. Nature, in its several decompositions, reduces almost all the principles of bodies into gas. These new substances unite together, combine, and from thence result compounds of considerable simplicity in their principles, but which become complicated by subsequent mixtures and combinations. We may follow the operations of nature, step by step, without departing from the plan we have adopted.

The mixture of about seventy-eight parts of nitrogene gas, and twenty-two of oxigene, form this fluid mass in which we live. These two principles are so well mixed, and each of them is so necessary to the support of the various functions of individuals which live or vegetate upon the globe, that they have not yet been found separate and alone.

The proportion of these two gases is subject to variation in the mixture which forms the atmosphere : but this difference depends only upon local causes ; and the most usual proportion is that which we have here mentioned.

† Combined with hydrogene it forms ammoniac, and with oxigene the nitric acid.—*Am. Ed.*

The characteristic properties of vital air are modified by those of nitrogene gas, and these modifications even seem to be necessary : for if we were to respire vital air in its state of purity, it would quickly consume our life ; and this virgin air is no more suitable to our existence than distilled water. Nature does not appear to have designed us for the use of these principles in their greatest degree of perfection.

The atmospheric air is elevated several leagues above our heads, and fills the deepest subterraneous cavities. It is invisible, insipid, inodorous, ponderous, elastic, &c. It was the only gaseous substance known before the present epocha of chemistry ; and the infinite gradations of all the invisible fluids which presented themselves so frequently to the observation of philosophers, were always attributed to modifications of the air. Almost the whole of what has been written upon the air relates only to its physical properties. We shall confine ourselves to point out the chief of these.

A. Air is a fluid of extreme rarefaction, obedient to the smallest motion : the slightest percussion deranges it ; and its equilibrium, which is continually destroyed, is continually endeavouring to restore itself.

Though very fluid, it passes with difficulty through orifices by means of which grosser liquids can easily penetrate. This has caused philosophers to suppose that its parts were of a branched form.*

B. The atmospheric air is invisible. It refracts the rays of light without reflecting them : for it is without sufficient proofs that some philosophers have imagined that large masses of this fluid are of a blue colour.

It appears that the air is inodorous itself ; though it is the vehicle of odorant particles.

It may be considered as insipid ; and when its contact affects us variously, we ought to attribute it to its physical qualities.

* This is a deception. It is true that the cohesive attraction renders it difficult to displace any dense fluid from a capillary tube by the intrusion of air ; but every experiment of the air-pump, the condensor, and the barometer, shews with what facility the air passes through the smallest orifices. T.

C. It was not until the middle of the last century that its weight was ascertained by accurate experiments. The impossibility of supporting water in a tube open at the bottom, to a greater height than thirty-two feet, caused Torricellius to suspect that an external cause supported the liquid at that height, and that it was not the horror of a vacuum which precipitated the water in the barrels of pumps. This celebrated philosopher filled a tube closed at one of its extremities with mercury: he reversed this into a vessel filled with the same metal; and observed that the mercury, after several oscillations, constantly subsided to the height of twenty-eight inches. He immediately saw that the difference of elevations corresponded with the relative weights of these two fluids, which are in the proportion of fourteen to one. The immortal Pascal proved, some time afterwards, that liquids were supported at this elevation by a column of atmospherical air; and he ascertained that their height varies according to the length of the column which presses upon them.

D. The elasticity of the air is one of the properties upon which natural philosophers have made the greatest number of experiments; and it has even been applied to considerable advantage in the arts.



SECTION VII.

Concerning the Combination of Oxigenous Gas and Hydrogene, which forms Water.

WATER has been long considered as an elementary principle; and when accurate experiments had compelled chemists to class it among compound substances, a resistance and opposition were made to it, which were not manifested when the air, the earth, and the other matters reputed to be elementary, were subjected to similar revolutions. It seems to me, however, that this analysis is equally strict with that of air. Water is decom-

posed by several processes ; it is formed by the combination of oxigene and hydrogene : and we find that all the phenomena of nature and art conspire to prove the same truth. What more can be required to afford an absolute certainty respecting any physical fact ?

Water is contained in bodies in a greater or less quantity, and may be considered in two states : it is either in the state of simple mixture, or in a state of combination. In the first case it renders bodies humid, is perceptible to the eye, and may be disengaged with the greatest facility. In the second, it exhibits no character which shews that it is in a state of mixture. It exists in this form in crystals, salts, plants, animals, &c. It is this water which the celebrated Bernard has called Generative Water ; and of which he has made a fifth element, to distinguish it from exhalative water.

Water, existing in a state of combination in bodies, concurs in imparting to them hardness and transparency. Salts, and most stony crystals, lose their transparency when they are deprived of their water of crystallization.

Some bodies are indebted to water for their fixity. The acids, for example, acquire fixity only by combining with water.

Under these various points of view, water may be considered as the general cement of nature. The stones and salts which are deprived of it, become pulverulent ; and water facilitates the coagulation, re-union, and consistence of the particles of stones, salts, &c. as we shall see in the operations performed with plasters, lutes, mortar, &c.

Water, when disengaged from its combinations, and in a state of absolute liberty, is one of the most considerable agents in the operations of this globe. It bears a part in the formation and decomposition of all the bodies of the mineral kingdom : it is necessary to vegetation and to the free exercise of most of the functions of animal bodies ; and it hastens and facilitates the destruction of these bodies, as soon as they are deprived of the principle of life.

For a certain time water was thought to be a fluid earth. The distillation, trituration, and putrefaction of water, which always left an earthy residue, afforded credit to an

opinion that it was converted into earth. On this subject, the works of Wallerius and Margraff may be consulted: but Mr. Lavoisier has shewn that this earth arises from the wear of the vessels; and the celebrated Scheele has proved the identity of the nature of this earth with that of the glass vessels in which the operations were made. So that the opinions of the philosophical world are at present decided in this respect.

In order to obtain accurate ideas of a substance so necessary to be known, we will consider water under its three different states of solidity, fluidity, and gas.

ARTICLE I.

Concerning Water in the State of Ice.

Ice is the natural state of water, whenever it is deprived of a portion of that caloric with which it is combined when it appears in the form of a liquid or gas.

The conversion into ice is attended with several phenomena which seldom vary.

A. The first of all, and at the same time the most extraordinary, is a sensible production of heat at the moment in which the water passes to the solid state. The experiments of Messrs. Fahrenheit, Treiwald, Baumé, De Ratte, leave no doubt on this subject; so that the water is colder at the instant of congelation than the ice itself.

A slight agitation of the fluid facilitates its conversion into ice, nearly in the same manner as the slightest motion very frequently determines the crystallization of certain salts. This arises, perhaps, from the circumstance, that by this means the caloric, which is interposed between the particles, and may oppose itself to the production of the phenomenon, may be expressed or disengaged. In proof of this opinion, it is seen that the thermometer rises at the very same instant, according to Fahrenheit.

B. Frozen water occupies a larger space than fluid water: we are indebted to the Academy del Cimento for the

proofs of this truth. In their experiments, bomb shells, and the strongest vessels, being filled with water, were burst into pieces by the congelation of this fluid. The trunks of trees are split and divided with a loud noise, as soon as the sap freezes; and so likewise stones are broken in pieces the moment the water, with which they are impregnated passes to the state of ice.

C. Ice appears to be nothing more than a confused crystallization. Mr. De Mairan observed that the needle-formed crystals of ice unite in an angle of either sixty or one hundred and twenty degrees.

Mr. Pelletier observed, in a piece of fistulous ice, crystals in the form of flattened triangular prisms, terminated by two dehdral summits.

Mr. Sage observes, that if a piece of ice, which contains water in its internal parts, be broken, the water runs out, and the internal cavity is found to be lined with beautiful tetrahedral prisms, terminated in four-sided prisms. These prisms are often articulated and crossed. Vide M. Sage, *Annales de Chimie*, tom. i. p. 77.

Mr. Macquart has observed, that when it snows at Moscow, and the atmosphere is not too dry, the air is observed to be loaded with beautiful crystallizations regularly flattened, and as thin as a leaf of paper. They consist of an union of fibres which shoot from the same centre to form six principal rays, and these rays divide themselves into small blades extremely brilliant: he observed several of these flattened radii which were ten lines in diameter.

D. When water passes from the solid to the liquid state, it produces cold by the absorption of a portion of heat, as is confirmed by the fine experiments of Wilcke. This production of cold by the fusion of ice, is likewise proved by the practice of the confectioners, who fuse certain salts with ice, in order to produce a degree of cold below 0.

Ice is found in many places in great masses, known by the name of *Glacieres*: certain mountains are constantly covered with them, and the southern ocean abounds with them. The ice formed by salt water affords fresh water when melted; and in several northern provinces water is said to be concentrated by frost, to collect the salt it holds

in solution. I have likewise observed, that several metallic salts are precipitated by exposing their solutions to a temperature sufficient to freeze them. The ice which was formed did not possess the characters of the salt which had been dissolved.

Hail and snow are nothing but modifications of ice. We may consider hail as produced by the sudden disengagement of the elastic fluid, which concurs in rendering water liquid : it is almost always accompanied with thunder. The experiments of Mr. Quinquet have confirmed this theory.—I will here relate a fact to which I myself was witness, at Montpellier, and of which philosophers may advantageously avail themselves. On the 29th of October, 1786, four inches of water fell at Montpellier, a violent explosion of thunder, which was heard about four in the evening, and which appeared to be very near, caused a most dreadful shower of hail. At this instant a druggist, who was employed in his cellar in preventing the mischief occasioned by the filtration of water through the wall, was highly astonished to behold that the water which came through the wall was instantly changed into ice. He called in several neighbours to partake of his surprise. I visited the place a quarter of an hour afterwards and found ten pounds of ice at the foot of the wall; I was well assured that it could not have passed through the wall, which did not exhibit any crack, but appeared to be in very good condition. Did the same cause, which determined the formation of hail in the atmosphere, act equally in this cellar?—I relate the fact only, and forbear to make any conjecture upon it.

ARTICLE II.

Concerning Water in the Liquid State.

THE natural state of water appears to be that of ice; but its most usual state is that of fluidity; and under this form it possesses certain general properties, which we shall proceed to describe.

The experiments of the Academy del Cimento have caused the philosophical world to deny the least elasticity

to water, because it escaped through the pores of balls of metal strongly compressed, rather than yield to pressure. But Messrs. Zimmerman, and the abbé Mongez, have endeavoured to prove its elasticity from the very experiments upon which the contrary opinion has been built.*

The liquid state renders the force of aggregation in water less powerful, and it enters into combination more readily in this form. Water which flows on the surface of our globe is never pure. Rain-water is seldom exempt from some mixture, as appears from the fine series of experiments of the celebrated Margraff. I have ascertained, at Montpellier, that the rain-water in storms is more impure than that of a gentle shower—that the water which falls first is less pure than that which falls after several hours or several days rain—that the water which falls when the wind blows from the sea to the southward, contains sea-salt; whereas that which is produced by a northerly wind, does not contain a particle.

Hippocrates has made several very important observations respecting the various qualities of water, relative to the nature of the soil, the temperature of the climate, &c.

As it is of importance to the chemist to have very pure water for several delicate operations, it is necessary to point out the means which may be used to carry any water whatever to this degree of purity.

Water is purified by distillation. This operation is performed in vessels called Alembics. The Alembic is composed of two pieces; a boiler or cucurbit, and a covering called the capital or head.

The water is put into the cucurbit, from which it is raised in vapours by means of fire, and these vapours are condensed by cooling the head with cold water. The condensed vapours flow into a vessel designed to receive them. This is called Distilled Water; and is pure, be-

* The experiments of Canton, to prove the compressibility of water, are well known, and may be seen in the Philosophical Transactions. He enclosed water in spherical glass vessels, from which a narrow neck proceeded, like that of a thermometer: the water was found to occupy a larger space when the pressure of the atmosphere was removed by the air pump, and a less space when a greater pressure was added by the condensor. T.

cause it has left behind it in the cucurbit the salts and other fixed principles which altered its purity.

Distillation is more speedy and quick, in proportion as the pressure of the air is less upon the surface of the stagnant fluid. Mr. Lavoisier distilled mercury *in vacuo*; and the abbé Rochon has made a happy application of these principles to distillation. It is to this same principle that we must refer the observations of almost all naturalists and philosophers, who have remarked, that the ebullition in the liquid becomes more easy, in proportion as we ascend a mountain from any other elevation; and it is in consequence of these principles, that Mr. Achard constructed an instrument to determine the heights of mountains, by the degrees of temperature of the ebullition of boiling water.

The abbé Mongez, and Mr. Lamanow, observed that ether evaporates with prodigious facility upon the peak of Teneriffe; and Mr. De Saussure has confirmed these experiments on the mountains of Switzerland.

A true distillation is carried on every where at the surface of our globe. The heat of the sun raises water in the form of vapours; these remain a certain time in the atmosphere, and afterwards fall in the form of dew, by simple refrigeration. This rise and fall of humidity, which succeed each other, wash and purge the atmosphere of all those particles, which by their corruption or development might render it infectious; and it is perhaps this combination of various miasmata with water which renders the evening dew so unwholesome.

It is to a similar natural distillation that we ought to refer the alternate transition of water from the liquid state to that of vapour, which forms clouds, and by this means conveys the water from the sea to the summits of mountains, from which it is precipitated in torrents, to return again to the common receptacle.

We find traces of the distillation of water in the most remote ages. The first navigators in the islands of the Archipelago filled their pots with salt-water, and received the vapour in sponges placed over them. The process of distilling the water of the sea has been successively brought to perfection; and Mr. Poissonnier has exhibited

a very well constructed apparatus to procure fresh water at all times in abundance.

Pure water requires to be agitated, and combined with the air of the atmosphere, to render it wholesome. Hence no doubt, it is, that water immediately produced by melting snow, is unfit to drink.

The characters of potable water are the following :

1. A lively, fresh, and agreeable taste.
2. The property of boiling readily, and also that of boiling peas, and other pulse.
3. The virtue of dissolving soap without curdling.

ARTICLE III.

Concerning Water in the State of Gas.

MANY substances are naturally in the state of an æriform fluid, at the degree of the temperature of our atmosphere: such, for example, are the carbonic acid; and the oxygenous, the hydrogenous, and the nitrogenous gases.

Other substances evaporate at a degree of heat very near that in which we live. Ether and alcohol are in this situation. The first of these liquors passes to the state of gas at the temperature of 35 degrees; the second, at that of 80 (of Reaumur.)

Some fluids require a stronger heat for this purpose; such as water, the sulphuric and nitric acids, oil, &c.

To convert water into an æriform fluid, Messrs. De la Place and Lavoisier filled a glass vessel with mercury, and reversed it over a dish filled with the same metal. Two ounces of water were transferred beneath this vessel; and the mercury was heated to the temperature of between ninety-five and a hundred of Reaumur, by plunging it in a boiler filled with the mother water of nitre. The included water became rarefied, and occupied the whole capacity.

Water, by passing through earthen vessels ignited in the fire, becomes converted into gas, according to Priestley and Kirwan. The eolipile, the steam-engine, the digester of Papin, and the process of the glass-blowers, who

blow large globes by injecting a mouthful of water through their iron tube, prove the conversion of water into gas.

It follows from these principles, that the volatilization of water being nothing more than a direct combination of caloric with this liquid, the portions of water which are the most immediately exposed to heat, must be the first volatilized: and this is daily observed; for it is continually seen that ebullition begins at the part most heated. But when the heat is applied equally at all parts, the ebullition is general.

Several phenomena have led us to believe that water may be converted into air. The process of the glass-blowers to blow large spheres; the hydraulic organ of father Kircher; the phenomena of the eolipile; the experiments of Messrs. Priestley and Kirwan; the manner of assisting combustion, by sprinkling a small quantity of water upon the coals—all these circumstances appeared to announce the conversion of water into air. But it was far from being supposed that most of these phenomena were produced by the decomposition of this fluid; and the genius of Mr. Lavoisier was necessary to carry this point of doctrine to the degree of certainty and precision, which in my opinion it now appears to possess.

Messrs. Macquer and De la Metherie had already observed, that the combustion of inflammable air produced much water. Mr. Cavendish confirmed these experiments in England, by the rapid combustion of inflammable air and vital air. But Messrs. Lavoisier, De la Place, Monge, and Meusnier, have proved that the whole mass of the water might be converted into hydrogene and oxigene; and that the combustion of these two gases produced a volume of water proportioned to the weight of the two principles employed in this experiment.

1. If a small glass vessel be inverted over mercury, and a known quantity of distilled water and filings of iron be put into the upper part of this vessel, inflammable air will be gradually disengaged, the iron will rust, and the water which moistens it will diminish, and at length disappear; the weight of the inflammable air which is produced, and the augmentation in weight of the iron, will be equivalent to the weight of the water made use of. It appears there-

fore to be proved, that the water is reduced into two principles, the one of which is inflammable air, and the other is the principle which has entered into combination with the metal. Now we know that the oxidation or calcination of metals is owing to vital air; and consequently the two substances produced, namely the vital air and inflammable air, arise from the decomposition of water.

2. When water is converted into the state of vapour, in its passage through an ignited iron tube, the iron becomes oxidized, and hydrogen is obtained in the state of gas. The augmentation of weight in the metal, and the weight of the hydrogen obtained form precisely a sum equal to that of the water employed.

The experiment made at Paris, in the presence of a numerous commission of the Academy, appears to me to leave no further doubt concerning the decomposition of water.

A gun-barrel was taken, into which a quantity of thick iron wire, flattened by hammering, was introduced. The iron and the gun-barrel were weighed: the gun-barrel was then covered with a lute proper to defend it from the contact of the air; it was afterwards placed in a furnace, and inclined in such a manner as that water might run through it. At its most elevated extremity was fixed a funnel designed to contain water, and to let it pass drop by drop by means of a cock: this funnel was closed, to avoid all evaporation of the water. At the other extremity of the gun-barrel was placed a tubulated receiver, intended to receive the water which might pass without decomposition; and to the tubulure of the receiver the pneumatological apparatus was adapted. For greater precaution, a vacuum was made in the whole apparatus before the operation began. Lastly, as soon as the gun-barrel was red-hot, the water was introduced drop by drop. Much hydrogenous gas was obtained: and at the end of the experiment the gun-barrel was found to have acquired weight; and the flat pieces of iron included within were converted into a stratum of black oxide of iron, or Ethiops martial, crystallized like the iron ore of the island of Elba. It was ascertained that the iron was in the same state as that which is burned in oxygenous gas; and the increased

weight of the iron, added to that of the hydrogene, was accurately equal to that of the water employed.

The hydrogenous gas obtained was burned with a quantity of vital air equal to that which had been retained by the iron, and the six ounces of water were recomposed.

3. Messrs. Lavoisier and De la Place, by burning in a proper apparatus a mixture of fourteen parts of hydrogenous gas, and eighty-six of oxigene, obtained a proportionate quantity of water. Mr. Monge obtained the same result at Mezieres, at the same time.

The most conclusive and the most authentic experiment which was made upon the composition or synthesis of water, is that which was begun on the 23d of May, and ended on the 7th of June, 1788, at the Royal College, by Mr. Lefevre de Gineau.

The volume of oxigenous gas consumed, when reduced to the pressure of twenty-eight inches of mercury, at the temperature of ten degrees of the thermometer of Reaumur, was 35085 (French) cubic inches, and its weight 250 gross 10,5 grains.

The volume of hydrogenous gas was 74967,4 cubic inches, and the weight 66 gross 4,3 grains.

The nitrogenous gas and the carbonic acid which were mixed with these gases, and which had been extracted out of the receiver at nine several times, weighed 39,23 grains.

The oxigenous gas contained $\frac{1}{3\frac{1}{8}}$ of its weight of carbonic acid; so that the weight of these gases burned was 280 gross 63,8 grains, which makes 2 pounds 3 ounces 0 gross 63,8 grains.

The vessels were opened in the presence of the gentlemen of the Academy of Sciences, and several other learned men, and were found to contain 2 pound 3 ounces 0 gros 33 grains of water: this weight answers to that of the gases made use of, wanting 31 grains; this deficiency may arise from the caloric which held the gases in solution being dissipated when they became fixed, which must necessarily have occasioned a loss.

The water was subacid to the taste, and afforded $27\frac{1}{2}$ grains of nitric acid, which acid is produced by the combination of the nitrogene and oxigene gases.

From the experiment of the decomposition of water, 100 parts of this fluid contained

Oxigene	$84,2636 = 84\frac{1}{4}$
Hydrogene	$15,7364 = 15\frac{3}{4}$

According to the experiment of its composition, 100 parts of water contained

Oxigene	$84,8 = 84\frac{4}{5}$
Hydrogene	$15,2 = 15\frac{1}{5}$

Independent of these experiments of analysis and synthesis, the phenomena exhibited by water, in its several states, confirm our ideas with regard to the constituent parts which we acknowledge it to possess. The oxidation of metals in the interior parts of the earth, at a distance from the atmospherical air, the efflorescence of pyrites, and the formation of ochres, are phenomena which cannot be explained without the assistance of this theory.

Water being composed of two known principles, must act like all other compound bodies which we know; that is, according to the affinities of its constituent parts. It must therefore in some instances yield its hydrogen, and in others its oxygen.

If it be placed in contact with bodies which have the strongest affinity with oxygen, such as the metals, oils, charcoal, &c. the oxygenous principle will unite with these substances; and the hydrogen, being set at liberty, will be dissipated. This happens when hydrogen gas is disengaged, by causing the acids to act upon certain metals; or when red-hot iron is plunged in water, as Messrs. Hassenfratz, Stoullz, and D'Hellancourt have observed.

In vegetables, on the contrary, it seems that the hydrogen is the principle which fixes itself; while the oxygen is easily disengaged, and makes its escape.

SECTION VIII.

Concerning the combinations of Nitrogene Gas. 1. With Hydrogene Gas. 2. With the Earthy Principles forming the Alkalis.

IT appears to be proved, that the combination of nitrogene gas with hydrogen forms one of the substances comprised in the class of alkalis. It is very probable that the others are composed of this same gas and an earthy basis. It is from these considerations that we have thought proper to place those substances here: and we have adopted that decision with so much the more foundation, because the knowledge of alkalis is indispensably necessary to enable us to proceed with order in a course of chemistry; and because these re-agents are most frequently employed, and their combinations and uses present themselves at every step in the phenomena of nature and art.

It is an established convention to call every substance an Alkali, which is characterized by the following properties:

A. An acrid, burning, urinous taste.

B. The property of converting blue vegetable colours green;* but not the tincture of turnsol, as certain authors announce.

C. The virtue of forming glass, when fused with quartzose substances.

D. The faculty of rendering oils miscible with water; of effervescing with certain acids; and of forming neutral salts with all of them.

I must observe that none of these characters is rigorous and exclusive; and that consequently no one of them is sufficient to afford a certainty of the existence of an alkali: but the re-union of several form, by their concurrence, a mass of proofs or indications, which lead us to sufficient evidence.

* Indigo is an exception to this law. The alkalis have no effect upon this blue vegetable colouring matter.—*Am. Ed.*

The alkalis are divided into fixed alkalis, and volatile alkalis. This distinction is established upon the smell of these substances: the former are not volatilized, even in the focus of the burning mirror, and emit no characteristic smell; whereas the latter are easily reduced into vapour, and emit a very penetrating odour.

CHAPTER I.

Concerning Fixed Alkalis.

NO more than two kinds of fixed alkalis have hitherto been discovered: the one which is called Vegetable Alkali, or Potash; the other Mineral Alkali, or Soda.

ARTICLE I.

Concerning the Vegetable Alkali, or Pot-Ash.

This alkali may be extracted from various substances; and it is more or less pure, accordingly as it is afforded by one substance or another. Several varieties are made in commerce, to which different names have been affixed, and which are indispensably necessary to be known. The chemist may indeed confound all these distinctions, in his writings, under one single denomination: but the distinctions established by the artists are founded upon a series of experiments, which have proved that the virtues of these several alkalis are very different; and this constant variety in their effects appears to me to justify the various denominations assigned them.

1. The alkali extracted from the lixivium of wood-ashes, is known by the name of *Salin*. The *salin* calcined, and by this means disengaged from all the blackening principles, forms potash.

The ashes are more or less rich in alkali, according to the nature of the wood which affords them; in general, hard woods contain the most.* The ashes of beech afford from 11 to 13lb. per quintal, according to the experiments which I have made in the large way, at St. Saviour; those of box afforded from 12 to 14lb. The tables drawn up by the several administrators of the gunpowder and saltpetre manufactories may be consulted, respecting the quantity of alkali afforded by the combustion of several plants: they used 4000lb. of each in their various experiments.†

To extract this alkali, nothing more is necessary than to wash the ashes, and to concentrate the dissolution in boilers of cast iron. It is on account of the alkali, that wood-ashes are employed in the lixiviums used by laundresses or bleachers. The use of alkali, in this case, is to combine with the fat substances, and to render them soluble in water.

Almost all the potash sold in commerce for the use of our glass-houses, our soap-makers, our bleaching-grounds, &c. is fabricated in the north, where the abundance of wood admits of its been applied to this single purpose. We might establish works of this kind to sufficient advantage in the forests of our kingdom. But there is more to be done than is generally supposed, before the inhabitants of the mountains can be turned towards this species of industry. I have experienced this difficulty in the attempts,

* Fourcroy says, more potash is generally extracted from tender than from hard wood. There is more from the rind of fruits, than from any other parts.—*Am. Ed.*

† According to these experiments,

		Pounds.	Ounces.	Drachms.	Grains.
4000 pounds of	Turnsol yielded	80	0	0	0
	Indian Corn -	70	8	6	13
	Tendrils of vines	23	4	4	0
	Elm - -	15	10	4	0
	Willow-tree -	11	9	6	18
	Box-wood - -	8	15	7	48
	Oak - - -	6	2	3	44
	Beech - - -	5	13	4	42
	Horn-bean -	6	0	1	69
	Aspin - - -	3	0	1	13
	Pine or Fir-tree -	1	5	2	6

Am. Ed.

and very considerable sacrifices which I have made, to secure this resource in the neighbourhood of Laigoual and Lesperou. The accurate calculations which I have made, have nevertheless proved that the potash would cost only from 15 to 17 livres the quintal, whereas we purchase that from the north at 30 or 40 livres.

2. The lees of wine are almost totally converted into alkali by combustion. This alkali is called *Cendres Gravelées*: it has almost always a greenish colour. This alkali is considered as very pure.

3. The combustion of tartar of wine likewise affords an alkali of considerable purity. It is usually burned wrapped up in paper, in small packets, which are dipped in water, and afterwards exposed upon burning coals. In order to purify it, the residue of the combustion is dissolved in water, the solution concentrated by fire, the foreign salts separated in proportion as they precipitate; and a very pure alkali is at last obtained, which is known by the name of Salt of Tartar.

To procure salt of tartar more speedily, as well as more economically, I burn a mixture of equal parts of nitrate of potash, or common nitre and tartar. The residue, after lixiviation, affords a beautiful salt of tartar.

Salt of tartar is the alkali most commonly employed in medical uses; it is given in the dose of several grains.

4. If saltpetre be fused upon charcoal, the acid is decomposed and dissipated, while the alkali remains alone and disengaged: this is called *Extemporaneous Alkali*.*

When the vegetable alkali has been brought to the greatest state of purity, it attracts the humidity of the air, and is resolved into a liquor. In this state it is known by the very improper name of *Oil of Tartar per deliquium*.

* In this case the carbone combines with the oxigene of the nitric acid of the nitre, and forms carbonic acid gas, which with the azotic air of the acid flies off. The potash of the nitre remains behind.—*Am. Ed.*

ARTICLE II.

Concerning the Mineral Alkali, or Soda.

The Mineral Alkali has been so called, because it forms the basis of marine salt.

It is obtained from marine plants by combustion: for this purpose heaps of the saline plants are formed; and at the side of these heaps a round cavity is dug, which is enlarged towards the bottom, and is three or four feet in depth: this is the fire-place in which the vegetables are burned. The combustion is kept up without interruption for several days; and when all the plants are consumed, a mass of alkaline salt is found remaining, which is cut into pieces, to facilitate its carriage and sale. This is known by the name of Rock Soda, or Soda.

All marine plants do not afford soda of the same quality. The barilla of Spain affords the beautiful soda of Alicant. I am assured that we might cultivate it upon our coasts in the Mediterranean, with the greatest success. This culture is highly interesting to the arts and commerce; and government ought to encourage this new species of industry. But an individual, however inclined or devoted to the public good, might make vain efforts to appropriate this commerce to our advantage, if he were not powerfully assisted by government; because the Spanish ministry has prohibited the exportation of the seed of barilla, under the strongest penalties. In Languedoc, and in Provence, we cultivate on the banks of our ponds a plant known by the name of Salicor, which affords soda of a good quality; but the plants which grow without cultivation produce an inferior sort. I have made an accurate analysis of each species, the results of which may be seen at the article *Verrierie* of the *Encyclopedie Methodique*. *

* Mr. Henry Mackenzie has given an account of the mode of making soda in Scotland, in an essay published in the prize essays and transactions of the Highland Society.

He informs us that the whole soda of Scotland is in general afforded by the four following plants;

First. *Fucus vesiculosus*, the most common sea-wrack, called also the sea-oak, from the resemblance of its leaves to those of the oak.

The mineral alkali is cleared of all heterogeneous salts by dissolving it in water, and separating the several salts in proportion as they fall down. The last portion of the fluid being concentrated affords the soda, which crystallizes in rhomboidal octahedrons.

The mineral alkali is sometimes found in a native state: in Egypt it is known by the name of Natron. The two lakes of Natron described by Sicard and Mr. Volney, are situated in the desert of Chaiat, or St. Macaire, to the west of Delta. Their bed is a natural cavity of three or four leagues in length, and a quarter of a league in breadth; the bottom is solid and stony. It is dry during nine months in the year; but in winter a water of a violet-red colour oozes out of the earth, which fills the lake to five or six feet in depth: the return of the heat of summer evaporates this, and leaves a bed of salt behind it of two feet in thickness, which is dug out with bars of iron. The quantity obtained annually amounts to 36,000 quintals.

Mr. Proust found natron upon the schisti which form the foundation of the town of Angers; the same chemist likewise found it upon a stone from the saltpetriere of Paris.

The mineral alkali differs from the vegetable, because—1. It is less caustic. 2. It is so far from attracting humidity, that it effloresces in the air. 3. It crystallizes in rhomboidal octahedrons. 4. It forms different products with the same bases. 5. It is more proper for vitrification.

Do the alkalis exist ready formed in vegetables, or are they the product of the several operations made use of in extracting them?—This question has divided the opi-

Secondly. *Fucus nodosus*, knotted sea-wrack.

Thirdly. *Fucus serratus*, the jagged or serrated sea-wrack; and

Fourthly. *Fucus digitatus*, or tangle.

These four plants are rooted upon rocks or stones. They grow only on the shores, where they are entirely uncovered by the water at the lowest ebb.

In Spain soda is procured from the *salsola soda*, and *salsola salicornia* and *batis maritima*. The *zostera maritima* is burnt for this purpose on the borders of the Baltic. In France they use the *chenopodium maritimum*, and in the Canary islands the *mesembryanthemum chrystallinum*, or ice plant is cultivated for this purpose.—*Am. Ed.*

nions of chemists. Du Hamel and Grosse proved, in 1732, the existence of alkali in cream of tartar, by treating it with the nitric, sulphuric, and other acids. Margraff has given additional proofs of this, in a Memoir which forms the twenty-fifth of his collection. Rouelle read a Memoir to the academy on the 14th of June, 1769, upon the same subject: he even affirms that he was acquainted with this truth before the work of Margraff appeared.—See the *Journal De Physique*, vol. i.

Rouelle, and the marquis De Bullion, proved that tartar exists in must.

It must not be concluded from the existence of an alkali in vegetables, that this salt is there found in a disengaged state. On the contrary it is found combined with acids, oils, &c.

The alkalis, such as we have described them, even after they have been disengaged from every mixture, by solution, filtration, and evaporation, are not nevertheless in that state of purity and disengagement, which is necessary to be obtained in many cases: they are nearly in the state of neutral salts, by their combination with the carbonic acid. When it is required to disengage this acid, the alkali must be dissolved in water, and quick lime then slaked in the solution. This substance seizes the carbonic acid of the alkali, and gives out its caloric in exchange. We shall speak of the circumstances of this operation when we shall have occasion to treat of lime. The alkali being deprived of the carbonic acid, no longer effervesces with other acids: it is more caustic, and more violent in its action; unites more easily to oils; and is then called Caustic Alkali, Pure Potash, or Pure Soda.

When this alkali is evaporated, and brought into the dry form, it is known by the name of Lapis Causticus. The corrosive virtue of this substance depends principally upon the avidity with which it seizes humidity, and falls into deliquium.

The caustic alkali, as it is usually prepared, always contains a small quantity of carbonic acid, silicious earth, iron, lime, &c. Mr. Berthollet has proposed the following means of purifying it:—He concentrates the caustic lixivium until it has acquired a slight degree of consistence; at which period he mixes it with alcohol, and draws

off a portion by distillation. As soon as the retort is become cold, he finds it to contain crystals, mixed with a blackish earth, in a small quantity of liquor of a dark colour, which is separated from the solution of alkali, in the alcohol, which swims above like an oil. These crystals consist of the alkali saturated with the carbonic acid, and are insoluble in spirit of wine; the deposition consists of silicious earth, lime, iron, &c.

The caustic alkali in a state of great purity, dissolved in the alcohol, swims above the aqueous solution which contains the effervescent alkali. If the spirituous solution of alkali be concentrated on the sand-bath, transparent crystals are formed, which consist of the pure alkali itself: these crystals appear to be formed by quadrangular pyramids inserted one in another; they are very deliquescent, are soluble in water and in alcohol, and produce cold by their solution.—See the *Journal de Physique*, 1786, page 401.

The alkalis we have just spoken of, combine easily with sulphur.

This combination may be effected—1. By the fusion of equal parts of alkali and sulphur. 2. By digesting the pure and liquid alkali upon sulphur.—In these cases the alkali becomes of a reddish yellow colour.

The solutions of sulphur in alkali are known by the name of *Livers of Sulphur*, *Sulphures of Alkali*, &c. They emit an offensive smell, resembling that of rotten eggs. This is occasioned by the escape of the stinking gas, called *Hepatic Gas*.

The sulphur may be precipitated by acids; and the result of this precipitation is what the ancient chemists distinguished by the name of *Milk of Sulphur*, and *Magistery of Sulphur*.

These sulphures or hepars dissolve metals. Gold itself may be so divided by this means as to pass through filters. Stahl has supposed that Moses made use of this method to enable the Israelites to drink the golden calf.

Though the analysis of the two alkalis has not been made with strictness, several experiments lead us to believe that nitrogene is one of their principles. Mr. Thouvenel, having exposed washed chalk to the exhalations of animal substances in putrefaction, obtained nitrate of pot-

ash, or common nitre. I have repeated this experiment in a closed chamber of six feet square. Twenty-five pounds of chalk well washed in warm water, and exposed to the exhalation of bullock's blood in putrefaction during eleven months, afforded nine ounces of nitrate of lime, in a dried state; and three ounces one gross of crystals of nitrate of pot-ash, or common nitre.

The repeated distillation of soaps decomposes them, and affords ammoniac. Now the analysis of this last, by Mr. Berthollet, proves the existence of nitrogenous gas as one of its constituent parts. There is therefore room to apprehend that nitrogene gas is one of the principles of alkalis.

The experiments of Mr. Thouvenel, as well as my own, lead to believe that this gas when combined with lime, forms pot-ash, or the vegetable alkali; while its union with magnesia forms soda. This last opinion is supported by the experiments—1. Of Dehne, who obtained magnesia from soda (see Crell's Chemical Annals, 1781, page 53). 2. Of Mr. Deyeux, who obtained similar results, even before Mr. Dehne. 3. Of Mr. Lorgna, who obtained much magnesia by dissolving, evaporating, and calcining soda repeatedly (Journal de Physique, 1787). Mr. Osburgh confirmed these various experiments in 1785.

CHAPTER II.

Concerning Ammoniac, or the Volatile Alkali.

OUR researches have not hitherto exhibited more than one species of volatile alkali. Its formation appears to be owing to putrefaction; and though the distillation of some schisti affords it, yet this circumstance may be attributed to their origin, which is pretty generally ascribed to vegetable and animal decomposition. We find frequently enough, in these substances, the print of fishes, which is in favour of this opinion. Some plants

likewise afford volatile alkali ; for which reason they have been called Animal Plants. But the volatile alkali is more especially afforded by animal substances : the distillation of all their parts affords it in considerable abundance. Horns are employed in preference, because they are resolved almost entirely into oil and volatile alkali. The putrefaction of all animal substances produces volatile alkali ; and in this case, as well as in distillation, it is formed by the combination of its two constituent parts : for the analysis very often fails in exhibiting any alkali ready formed, in such parts as distillation or putrefaction would abundantly afford it from.

Almost all the volatile alkali made use of in commerce or medicine, is afforded by the decomposition of sal ammoniac. It is even on account of this circumstance, that the chemists who have drawn up the New Nomenclature, have distinguished the volatile alkali by the name of Ammoniac.

To obtain ammoniac in a state of considerable purity, equal parts of sifted quick-lime and muriate of ammoniac, or common sal ammoniac in powder, are mixed. This mixture is then introduced into a retort, to which a receiver and the apparatus of Woulfe have been adapted. A quantity of pure water is to be put into the bottles, correspondent to the weight of the salt employed ; and the junctures of the vessels are made good with the usual lutes. The ammoniac is disengaged in the state of gas, at the first impression of the fire. It combines with the water with heat ; and when the water of the first bottle is saturated, the gas passes to that of the second, and saturates it in its turn.*

Volatile alkali is known by its very strong but not disagreeable smell. It is easily reducible into the state of gas, and preserves this form at the temperature of the atmosphere. This gas may be obtained by decomposing the muriate of ammoniac by quick-lime, and receiving the product over mercury.

* * Put the sifted quick-lime and sal ammoniac into the oil flask, Plate i, fig. 2. apply the heat of the lamp, and the ammoniacal gas, will pass through the glass tube, and be absorbed by the water in the bottle.—*Am. Ed.*

Alkaline gas kills animals, and corrodes the skin. The irritation is such, that I have seen pimples arise all over the bodies of some birds exposed to its atmosphere.

This gas is improper for combustion; but if a taper be gently immersed in it, the flame is enlarged before it goes out, and the gas suffers a decomposition. Alkaline gas is lighter than atmospheric air; and has even been mentioned, on account of its lightness, as a proper substance to fill balloons. The count De Milly proposed to place a brazier, or vessel containing fire, under the balloon, to keep the gas in its greatest state of expansibility.

The experiments of Dr. Priestley, who changed alkaline gas into hydrogen gas by means of the electric spark; those of the chevalier Laudriani, who, by passing the same gas through ignited glass tubes, obtained a large quantity of hydrogenous gas—occasioned a suspicion of the existence of hydrogen among the principles of alkaline gas. But the experiments of Mr. Berthollet have removed all doubts on this subject; and all observations appear to unite in authorizing us to consider this alkali as a compound of the nitrogenous and hydrogenous gases.

1. If the oxygenated muriatic acid be mixed with very pure ammoniac, an effervescence takes place, with a disengagement of nitrogenous gas, a production of water, and a conversion of the oxygenated acid into the ordinary muriatic acid. In this beautiful experiment, the water which is produced is formed by the combination of the hydrogen of the alkali and the oxygen of the acid; and the nitrogenous gas being set at liberty, is dissipated.

If the oxides of copper or gold be heated with ammoniacal gas, the product is water and nitrogenous gas, and the metals are reduced.*

I have observed that the oxides of arsenic, being digested with ammoniac, are reduced, and often form octahedral crystals of arsenic. In this case there is a disengagement of nitrogenous gas, and a formation of water.

* Upon throwing the focus of a burning lens upon an oxide of gold or copper, confined in ammoniacal gas over mercury, the hydrogen of the ammoniac unites to the oxygen of the oxides, and forms water, the azotic air of the ammoniac is left behind. The metals by being deprived of their oxygen, are found in a revived state.—*Am. Ed.*

It very often happens when metals, such as copper or tin, are dissolved by means of the nitric acid diluted with water, that an absorption of air takes place, instead of a disengagement of nitrous gas, as might be expected; I have seen several persons very much embarrassed in such cases, and I have often been so myself. This phenomenon takes place more especially when a very concentrated acid is made use of,* and the copper is in fine filings: in this case ammoniac is produced. I have shewn this fact to my auditors long before I was acquainted with the theory of its formation. That which led me to suspect its existence, was the blue colour which the solution takes in this case. This ammoniac is produced by the combination of the hydrogen of the water with the nitrogen gas of the nitric acid; while the oxygen of the same acid, and that of the water, oxidized the metal, and prepared it for solution. It is to a similar cause that we must refer the experiment of Mr. John Michael Haussmann of Colmar, who by passing nitrous gas through a certain quantity of precipitate of iron, in the mercurial apparatus, observed that this gas was speedily absorbed, and the colour of the iron changed; at the same time that vapour of ammoniac was found in the vessels. It is by a similar theory we may account for the formation of alkaline gas, by the mixture of hepatic gas and nitrous gas over mercury, as Mr. Kirwan observes.

Mr. Austin formed ammoniac; but he observed that the combination of nitrogenous gas with the base of hydrogen does not take place unless this last is in a state of great condensation.

The formation of ammoniac by distillation and putrefaction, appears to me likewise to indicate its constituent parts. In fact, there is in both these operations a disengagement of hydrogen and nitrogen gas, and their combination produces ammoniac.

Mr. Berthollet has proved, by the way of decomposition, that one thousand parts of ammoniac, by weight, are composed of about eight hundred and seven of nitrogen gas, and one hundred and ninety-three of hydrogen gas.

* This is a mistake. Concentrated nitric acid has no action on copper.—*Am. Ed.*

—See the collection of the Royal Academy, 1784, page 316.

According to Dr. Austin, the nitrogen gas is in proportion to the hydrogen, as one hundred and twenty-one to thirty-two.*

SECTION IX.

Concerning the Combination of Oxigene with certain Bases forming Acids.

IT appears to be out of doubt, that the bodies which we are agreed to call Acids, are combinations of vital Air with a certain elementary substance. The analysis of almost all the Acids, whose component parts are known, establishes this truth in a positive manner; and it is on account of this property that the denomination of Oxigenous Gas has been given to vital air.

Every substance which possesses the following properties is called an Acid:

A. The word sour, which is usually employed to denote the impression or lively and sharp sensation produced on the tongue by certain bodies, may be regarded as synonymous to the word *acid*. The only difference which may be established between them is, that the one denotes a weak sensation, whereas the other comprehends all the degrees of force from the least perceptible taste to the greatest degree of causticity. We say, for example, that verjuice, gooseberries, or lemons, are *sour*; but we use the word *acid* to express the impression which the nitric, sulphuric, or muriatic acids make upon the tongue.

* It is asserted that ammoniac will give to new brandy, all the qualities of that of the oldest date. Five or six drops are to be poured into each bottle of brandy, which is to be well shaken.—*Am. Ed.*

The causticity of acids appears to arise from their strong tendency to combination; and it is from this property that the immortal Newton has defined them to be bodies which attract and are attracted.

It is likewise from this property that certain chemists have supposed acids to be pointed bodies.

On account likewise of this decided tendency to combination which acids possess, it seldom happens that we find them in a disengaged state.

B. A second property of acids is that of changing certain blue vegetable colours into red, such as the colour of turnsol,* &c. These two re-agents are commonly used to ascertain the presence of acids.

The tincture of turnsol is prepared by lightly infusing in water that substance which is known in common under the name of Turnsol or Litmus. If the water be too highly charged with the colouring matter, the infusion has a violet tinge, and must in that case be diluted with water until it becomes blue. The tincture of turnsol, when exposed to the sun, becomes red, even in closed vessels; and some time afterwards the colouring part is disengaged, and falls down in the form of a mucilaginous discoloured substance. Alcohol may be used instead of water in the preparation of this tincture.

It is generally supposed that the turnsol fabricated in Holland is nothing more than the colouring matter extracted from the rags or cloths of turnsol of Grand-Gallargues, and precipitated upon a marly earth. These rags are prepared by impregnating them with the juice of nightshade (*morelle*), and exposing them to the vapour of urine, which develops their blue colour. The rags are sent into Holland, which has given rise to the opinion that they are used in the fabrication of turnsol; but subsequent inquiries have taught me that these cloths are sent to the dealers in cheese, who extract a colour by infusion, and wash their cheeses with it, to give them a red colour. I am convinced, by the analysis of turnsol, that the colouring matter is of the same nature as that of archil (*orseille*): and that this principle is fixed on a calcareous earth, and a small quantity of pot-ash. In consequence of this ana-

* And in general all blue vegetable colours.—*Am. Ed.*

lysis, I have endeavoured to cause the liken parellus of Auvergne to ferment with urine, lime, and alkali; and I obtained a paste similar to that of turnsol. The addition of alkali appears to me to be necessary to prevent the development of the red colour, which when combined with the blue, forms the violet of the archil.

When any concentrated acid is to be tried with sirup of violets, there are two particulars to be attended to. 1. The sirup of violets is often green, because the petal of the violet contains a yellow part at its base, which, when combined with the blue, forms this green colour: it is therefore essential to employ only the blue of the petal in order to have a beautiful blue infusion. 2. Care must be taken to dilute the sirup with a certain quantity of water; because otherwise concentrated acids, such as the sulphuric, would burn it, and form a coal.

The simple infusion of violets may be used instead of the sirup.*

The colouring matter of indigo is not sensible to the impression of acids. The sulphuric acid dissolves it, without altering the colour.

C. A third character of acids is, that they effervesce with alkalis; but this property is not general. 1. Because the carbonic acid, and almost all weak acids, cannot be distinguished by this property. 2. Because the purest alkalis combine with acids, without motion or effervescence.

Is there not one single acid in nature, of which the others may be only modifications?

Paracelsus admitted an universal principle of acidity, which communicated taste and solubility to all its compounds.

Becher believed that this principle was composed of water and vitrifiable earth. Stahl endeavoured to prove that the sulphuric acid was the universal acid; and his opinion was adopted by most chemists for a long time.

Long after the time of Stahl, Meyer maintained that the acid element was contained in fire. This system,

* The sirup of violets cannot be procured in the United States. An infusion of the blue cabbage is one of the most delicate tests, to detect the presence of an acid or an alkali.—*Am. Ed.*

which is founded on certain known facts, has had its supporters.

The chevalier Landriani imagined he had succeeded in reducing all the acids to the carbonic acid; because, by treating them all with different substances, he obtained this last as the constant result of his analysis. He was led into an error, for want of having sufficiently attended to the decomposition of the acids he made use of, and the combination of their oxigene with the carbone of the bodies which entered into his experiments, and produced the carbonic acid.

Lastly, the strict analysis and synthesis of most of the known acids, have proved to Mr. Lavoisier that oxigene is the base of all of them; and that their differences and varieties arise only from the substance with which this common principle is combined.

Oxigene united with metals forms oxides; and among these last there are some which possess acid characters, and are classed amongst acid substances.

Oxigene combined with inflammable substances, such as sulphur, carbone, and oils, forms other acids.

The action of acids upon bodies in general cannot be understood but by founding our explanations upon the data which we have established respecting the nature of their constituent parts.

The adhesion of oxigene to the base is more or less strong in the several acids, and consequently their decomposition is more or less easy; as, for example, in metallic solutions, which do not take place excepting when the metal is in the state of an oxide. The acid which will yield its oxigene with the greatest facility to oxide the metal, will have the most powerful action upon it. Hence it happens, that the nitric and the nitro-muriatic acids are those which dissolve metals the most readily; and hence likewise it happens, that the muriatic acid dissolves the oxides more easily than the metals, while the nitric acid acts contrariwise: hence also it arises that this last acts so powerfully upon oils, &c.

It is impossible to conceive and explain the various phenomena presented to us by acids in their operations, if we have no idea of their constituent principles. Stahl would not have believed in the formation of sulphur, if he

had understood the decomposition of the sulphuric acid upon charcoal; and if we except the combinations of acids with alkalis, and with certain earths, these substances are either totally or partially decomposed in all the operations made with them upon metals, vegetables, and animals, as we shall find by observing the several phenomena exhibited in these cases respectively.

We shall at present treat only of some of the acids, and shall direct our attention to the others in proportion as we shall have occasion to treat of the various substances which afford them; we shall attend in preference to those which are the best known, and which have the greatest influence in the operations of nature, as well as in those of our laboratories.

CHAPTER I.

Concerning the Carbonic Acid.

THIS acid is almost always observed in the state of gas. We find that the ancients were in some measure acquainted with it. Van Helmont called it Gas Silvestre, the gas of must, or of the vintage. Becher himself had a considerably accurate notion of it, as appears by the following passage; “Distinguitur autem inter “fermentationem apertam et clausam; in apertâ potus fer-
“mentatus sanior est, sed fortior in clausâ: causa est, quod
“evaporantia rarefacta corpuscula, imprimis magna adhuc
“silvestrium spirituum copia, de quibus antea egimus, re-
“tineatur, et in ipsum potum se precipitet, unde valde
“eum fortem reddit.”

Hoffmann attributed the virtue of most mineral waters to an elastic spirit contained in them.

Mr. Venel, a celebrated professor in the schools at Montpellier, proved in 1750, that the waters of Seltzer owed their virtue to a superabundant portion of air.

In 1755, Dr. Black of Edinburgh advanced that limestone contains much air of a different nature from common

air. He affirmed that the disengagement of this air converted it into lime, and that by the restoration of this air calcareous stone was regenerated. In the year 1746, Dr. M'Bride supported this doctrine with new facts. Mr. Jacquin, professor of Vienna, resumed the same pursuit, multiplied experiments on the manner of extracting this air, and added other proofs in confirmation that the absence of the air rendered alkalis caustic, and formed lime. Dr. Priestley exhibited all the perspicuity and precision on this subject which might be expected from his abilities, and his skill in making experiments of this kind. This substance was then known by the name of Fixed Air. In 1772, Bergmann proved that it is an acid, which he called by the name of Aërial Acid. Since the time of this celebrated chemist, it has been distinguished by the names of Mephitic Acid, Cretaceous acid, &c.: and as soon as it was proved to consist of a combination of oxigene and carbone, or pure charcoal, the name of Carbonic acid was appropriated to it.

The carbonic acid is found in three different states. 1. In that of gas. 2. In a state of mixture. 3. In a state of combination.

It is found in the state of gas at the Grotto del Cano, near Naples; at the well of Perols, near Montpellier; in that of Negrae in Vivarais; upon the surface of the Lake Averno in Italy, and on those of several springs; in various subterraneous places, such as tombs, cellars, necessaries, &c. It is disengaged in this form by the decomposition of vegetables heaped together, by the fermentation of wine or beer, by the putrefaction of animal matters, &c.

It exists in the state of simple mixture in mineral waters, since in these it possesses all its acid properties.

It exists in a state of combination in stone, common magnesia, alkalis, &c.

Various processes are employed to collect it, according to the state in which it is found.

1. When the carbonic acid exists in the state of gas, it may be collected—1. By filling a bottle with water, and emptying it into the atmosphere of this gas: the acid takes the place of the water, and the bottle is afterwards corked to retain it. 2. By exposing lime-water, caustic

alkalis, or even pure water, in its atmosphere; the gaseous acid mixes or combines with these substances; and may be afterwards extracted by re-agents, which we shall proceed to describe.

II. When the carbonic acid exists in a state of combination, it may be extracted—1. By distillation with a strong heat. 2. By the re-action of other acids, such as the sulphuric acid, which has the advantage of not being volatile, and consequently is not altered by its mixture with the carbonic acid which is disengaged.

III. When the carbonic acid exists in the state of simple mixture, as in water, brisk wines, &c. it may be obtained—1. By agitation of the liquid which contains it; as Mr. Venel practised, by making use of a bottle to which he adapted a moistened bladder.

2. By distillation of the same fluid.—These two first methods are not accurate.

The process indicated by Mr. Gioanetti, consists in precipitating the carbonic acid by means of lime water, weighing the precipitate, and deducting thirteen thirty-second parts for the proportion of carbonic acid; it having been deduced from analysis, by this celebrated physician, that thirty-two parts of carbonate of lime contain seventeen lime, two water, and thirteen acid.

This substance is an acid, as is proved—1. Because tincture of turnsol, agitated in a bottle filled with this gas, becomes red. 2. Ammoniac, or volatile alkali, poured into a vessel filled with this gas, is neutralized. 3. Water impregnated with this gas, is strongly sub-acid. 4. It neutralizes alkalis, and causes them to crystallize.

It remains at present to examine the properties of this acid gas.

A. It is unfit for respiration. History informs us that two slaves whom Tiberius caused to descend into the Grotto del Cano, were immediately stifled; and two criminals that Peter de Toledo caused to be shut in there, suffered the same fate. The abbé Nollet, who had the courage to respire the vapour, perceived a suffocating sensation, and a slight degree of acidity, which produced coughing and sneezing. Pilatre de Rosier, who presents himself to our notice on all occasions wherein danger was to be faced, caused himself to be fastened by cords fixed

under his arms, and descended into the gaseous atmosphere of a back of beer in fermentation. He had scarcely entered into the mephitic before slight prickings obliged him to shut his eyes; a violent suffocation prevented him from respiring, he felt a giddiness, accompanied with those noises which characterize the apoplexy: and when he was drawn up, his sight remained dim for several minutes; the blood had filled the jugulars; his countenance had become purple; and he neither heard nor spoke but with great difficulty: all these symptoms however disappeared by degrees.

It is this gas which produces the many unhappy accidents at the opening of cellars, in places where wine, cider, or beer are suffered to ferment. Birds plunged into the carbonic acid gas, suddenly perish. The famous lake of Averno, where Virgil placed the entrance of hell, exhales so large a quantity of carbonic acid, that birds cannot fly over it with impunity. When the waters of Bouldou of Perols are dry, such birds as attempt to quench their thirst in the clefts, are enveloped in the mephitic vapour, and die.

Frogs, plunged in an atmosphere of carbonic acid, live from forty to sixty minutes, by suspending their respiration.

Insects are rendered torpid after a certain time of remaining in this air; but they resume their liveliness the moment they are exposed to the free air.

Bergmann pretended that this acid suffocates by extinguishing irritability: he founds his opinion upon the circumstance of his having taken out the heart of an animal which had died in the carbonic acid, before it was cold, and it exhibited no sign of irritability. The chevalier Landriani has proceeded still further: for he affirms that this gas extinguishes irritability, even when applied to the skin; and has asserted that, by tying a bladder full of this gas to the neck of a fowl, in such a manner that the head only of the animal was in the open air, and the whole body enveloped in the bladder, the fowl immediately perished. The abbé Fontana has repeated and varied this experiment on several animals, none of which died.

The count Morozzo published experiments made in the presence of Dr. Cigna; the results of which appear

to invalidate the consequences of the celebrated Bergmann : but it is to be observed, that the chemist of Turin caused his animals to die only in air vitiated by the death of another animal ; and that in this circumstance the nitrogene gas predominates.—See the *Journal de Physique*, tom. xxv. p. 112.

B. The carbonic acid is improper for vegetation. Dr. Priestley having kept the roots of several plants in water impregnated with the carbonic acid, observed that they all perished ; and in those instances where plants are observed to vegetate in water or in air which contains this gas, the quantity of gas is very small.

Mr. Senebier has even observed, that plants which are suffered to grow in water slightly acidulated with this gas emit a much larger quantity of oxygenous gas ; because, in this case, the acid is decomposed, the carbonaceous principle combines, and is fixed in the vegetable, while the oxygen is thrown off.*

I have observed that those fungi which are formed in subterraneous places, are almost totally resolved into carbonic acid ; but if these vegetables be gradually exposed to the action of light, the proportion of acid diminishes ; while that of the coaly principle augments, and the vegetable becomes coloured. I have pursued these experiments with the greatest care in a coal mine.

C. The carbonic acid is easily dissolved in water. Water impregnated with this acid possesses very valuable medicinal qualities ; and several apparatus have been successively invented to facilitate this mixture. The apparatus of Nouth, improved by Parker and Magellan, is one of the most ingenious. On this subject the *Encyclopédie Methodique* may be consulted, article *Acide Mephitique*.

The natural acidulous mineral waters do not differ from these, excepting in consequence of their holding other principles in solution ; and they may be perfectly imitated

* The water which Dr. Priestley used, was too strongly impregnated with carbonic acid. Water containing a small portion of the air, is favourable to vegetation. It acts as a gentle stimulant to the plant, and is decomposed by it ; whereas too large a quantity of the fixed air, brings on indirect debility in the vegetable, and destroys it.—*Am. Ed.*

when their analysis is well known. It is absurd to think that art is incapable of imitating nature in the composition of mineral waters. It must be admitted that the processes of nature are absolutely unknown to us, in all the operations which relate to life; and we cannot flatter ourselves with the hope of imitating her in these circumstances. But when the question relates to an operation purely mechanical, or consisting of the solution of certain known principles in water, we can and ought to perform it even still better, as we have the power of varying the doses, and proportioning the efficacy of any artificial mineral water to the purposes to which it is intended to be applied.

D. The carbonic acid gas is heavier than common air. The proportion between these two airs in weight, according to Mr. Kirwan, is 45,69 to 68,74. The proportion according to the experiments of Mr. Lavoisier, is 48,81 to 69,50.

This considerable weight causes it to occupy the lowest situations; and even gives it the property of being poured out from one vessel to another, so as to displace the atmospheric air. This truly curious phenomenon was observed by Mr. De Sauvages, as may be seen in his Dissertation upon air, which was crowned in Marseilles in 1750.

It appears to be proved, by sufficient experiments, that the carbonic acid is a combination of carbone, or pure charcoal and oxigene. 1. The oxides of mercury, when distilled, are reducible without addition, and afford only oxigenous gas; but if a small quantity of charcoal be mixed with the oxide, the product which comes over consists of carbonic gas only, and the weight of the charcoal is diminished.

2. If well-made charcoal be ignited, and plunged into a vessel filled with oxigenous gas, and the vessel be instantly closed, the charcoal burns rapidly, and at last goes out: the product in this experiment is carbonic acid, which may be separated by the known processes; the remainder is a small quantity of oxigenous gas, which may be converted into carbonic acid by the same treatment.*

* Carbonic acid may be decomposed, by boiling phosphorus in a solution of the carbonate of potash; or by exposing small pieces of

In these experiments I see nothing but charcoal and oxygenous gas; and the consequence deduced is simple and natural.

The proportion of charcoal is to that of oxygen as 12,0288 to 56,687.

When the carbonic acid, in some cases, is obtained by burning hydrogenous gas, it arises from carbone held in solution in this gas. The carbone may even be dissolved in hydrogenous gas, by exposing it to the focus of the burning mirror in the mercurial apparatus, under a glass vessel filled with this gas.

The hydrogenous gas which is extracted from a mixture of sulphuric acid and iron, holds more or less of charcoal in solution; because iron itself contains this substance in a greater or less quantity, as is ascertained by the fine experiments of Messrs. Berthollet, Monge, and Vander Monde.*

The alkalis, such as we usually meet with them, contain carbonic acid; and it is this acid which modifies them, and diminishes their energy, at the same time that it communicates to them the property of effervescing. We may therefore consider alkalis as carbonates with excess of alkali; and it is easy to saturate this superabundant alkali, and to form true crystallizable neutral salts.

ARTICLE I.

Carbonate of Potash.

The carbonate of pot-ash was formerly distinguished by the name of Cretaceous Tartar. The method of causing

phosphorus and limestone in powder to a red heat, in a glass tube, which should be coated with a mixture of dung and clay. The oxygen of the carbonic acid, of the carbonates of pot-ash or lime, will unite with the phosphorus and form phosphoric acid, which will join to the pot-ash and lime, making phosphates of lime and pot-ash. The carbone of the carbonic acid will be deposited among these phosphates.—*Am. Ed.*

* An ounce of bar iron does not contain more than half a grain of charcoal, whereas the same quantity of cast iron contains from twelve to twenty grains.—*Am. Ed.*

oil of tartar to crystallize, has long been known. Bonhius and Montet have successively shewn these processes: but the simplest consists in exposing an alkaline solution in an atmosphere of the acid gas which is disengaged in the vinous fermentation; the alkali becomes saturated, and forms tetrahedral prismatic crystals terminated by very short four-sided pyramids.

I have several times obtained those crystals in the form of quadrangular prisms, with their extremities cut off slantwise.

This neutral salt no longer possesses the urinous taste of the alkali, but exhibits the penetrating taste of neutral salts, and may be employed in medicine with the greatest success. I have been a witness to its being taken in the dose of one dram (gross) without the least inconvenience.

This salt possesses an advantage beyond the salt of tartar, in being less caustic, and always of the same virtue.*

It contains, according to the analysis of Bergmann, twenty parts acid, forty-eight alkali, and thirty-two water, in the quintal.

It does not attract the humidity of the air. I have preserved some of it for several years in a capsule, without any appearance of alteration.

The carbonate of potash is decomposed by silex in a sufficient heat, which occasions a considerable boiling or ebullition. The residue is glass, in which the alkali is in the caustic state. Lime decomposes the carbonate, by uniting to the acid; and acids produce the same effect, by combining with the alkaline bases.

ARTICLE II.

Carbonate of Soda.

The denominations of Aërated Mineral Alkali, Cretaceous Soda, &c. have been successively given to this kind of carbonate.

The mineral alkali, in its natural state, contains a greater quantity of carbonic acid than the vegetable; and nothing

* It is preferable to the common alkali in making the effervescing or anti-emetic draught of Riverius.—*Am. Ed.*

more is necessary than to dissolve it, and duly evaporate the water, in order to obtain it in crystals.

These crystals are usually rhomboidal octahedrons; and sometimes have the form of rhomboidal laminæ, applied obliquely one upon the other, so that they resemble tiles.

This carbonate effloresces in the air.

One hundred parts contain sixteen parts acid, twenty alkali, and sixty-four water.

The affinity of its basis with silex is stronger than that of the carbonate of potash; in consequence of which, the vitrification it produces is more quick and easy.

Lime and the acids decompose it, with the same phenomena which we have observed at the article Carbonate of Potash.

ARTICLE III.

Carbonate of Ammoniac.

This salt has been generally known by the name of Concrete Volatile Alkali. It has likewise been distinguished by that of Cretaceous Volatile Alkali, &c.

It may be obtained by distillation from many animal substances. Tobacco affords, likewise, a large proportion; but almost the whole of that which is employed in the arts, and in medicine, is formed by the direct combination of the carbonic acid and ammoniac, or volatile alkali. This combination may be effected—1. By passing the carbonic acid through ammoniac, or the pure volatile alkali in solution. 2. By exposing ammoniac in an atmosphere of carbonic acid gas. 3. By decomposing the muriate of ammoniac by the neutral salts which contain this acid, such as the carbonate of lime or common chalk. For this purpose, white chalk is taken, and very accurately dried; and then mixed with equal parts of muriate of ammoniac, or common sal ammoniac in fine powder. This mixture is put into a retort, and distilled; the ammoniac and the carbonic acid being disengaged from their bases, and reduced into vapours, combine together, and are deposited on the sides of the receiver, where they form a stratum more or less thick.

The crystallization of this carbonate appeared to me to be that of a four-sided prism, terminated by a dihedral summit.

The carbonate has less smell than the ammoniac; it is very soluble in water. Cold water dissolves its own weight of this salt, at the temperature of sixty degrees of Fahrenheit.

One hundred grains of this salt contain forty-five parts acid, forty-three alkali, and twelve water, according to Bergmann.

Most acids decompose it, and displace the carbonic acid.*

* *Gaseous Oxide of Carbone, or Carbonic Oxide Gas.*

This air was discovered by Dr. Priestley in the year 1790, by exposing the scales which the blacksmiths strike off from red-hot iron, called by him finery cinder, to a red heat, mixed with the powder of charcoal. The experiment is related in the first volume of the Doctor's treatise on different kinds of air.

In some observations on the theory of chemistry, published at the end of the third volume, he refers to this experiment, and insists that it cannot be explained by the principles of the antiphlogistic system.

After the Doctor's arrival in America, he addressed a small pamphlet, entitled "Considerations on the Doctrine of Phlogiston and the Decomposition of Water," to Messrs. Berthollet, De la Place, Monge, Morveau, Fourcroy and Hassenfratz, the most eminent of the French chemists, and again made an attempt to call their attention to this experiment.

According to these gentlemen, says Dr. Priestley, inflammable air is nothing more than one of the component parts of water; but if this is a fact, "it never could be produced but in circumstances, in which either water itself, or something into which water is known to enter, is present. But in my experiments on heating finery cinder, together with charcoal, inflammable air is produced, though according to the new theory, no water is concerned. According to this theory, finery cinder, called the *oxide of iron*, consists of nothing besides iron and oxigene; and the charcoal made with the greatest degree of heat that can be applied, is equally free from water; and yet, when these two substances are mixed together, they yield inflammable air in the greatest abundance."

Two answers were immediately written to this performance of Dr. Priestley, one by Monsieur Adet, then Minister Plenipotentiary from the Republic of France to the United States of America, and the other by Dr. John Maclean, Professor of Chemistry in Princeton College, New-Jersey. Mr. Adet supposed, that the inflammable air came from the charcoal, to which it had a very strong affinity, and which

CHAPTER II.

Concerning the Sulphuric Acid.

SULPHUR, like every other combustible substance, cannot be burnt but by virtue of the oxygenous gas which combines with it.

it was very difficult to separate from it. This was also the opinion of Berthollet. Dr. Maclean declared that the experiment was of no value, but attempted to account for it by the presence of moisture in the retort or charcoal which was made use of.

Before these gentlemen replied to Dr. Priestley, I repeated this famous experiment, in the following manner :

An ounce of the scales of iron, and the same quantity of charcoal, were reduced to a very fine powder, and exposed separately in covered crucibles, in an air furnace, well supplied with fuel for five hours. They were then taken out of the fire, and mixed while red hot, in a red hot iron mortar, were triturated with a red hot pestle, formed of an iron ramrod, were poured upon a red hot sheet of iron, and instantly put into a red hot gun-barrel, which was fixed in one of Lewis's black lead furnaces, and which was connected with a pneumatic apparatus. One hundred and forty-two ounce measures of inflammable air, mixed with carbonic acid gas, were obtained in this experiment. The iron was revived.

Having discovered some time after this, that the calces of zinc, lead, tin, bismuth, copper and manganese, exposed a considerable time to a red heat, and then mixed with charcoal that had ceased to yield air, would afford large quantities of carbonic acid gas and inflammable air, and sometimes inflammable air without any mixture of fixed air, I pronounced that the result of these experiments could not be accounted for in a satisfactory manner, by the antiphlogistic system of chemistry.

A copy of the objections, which may be seen in the Medical Repository of New-York, vol. iv, p. 112, were sent to the National Institute of France, and they were immediately republished in one of the volumes of the Annals of Chemistry.

The objections were conceived as valid, until Mr. Cruikshank* of Woolwich, Great-Britain, having repeated these experiments, and found them accurate, made a successful analysis of the air obtained by exposing metallic calces and coal to heat, and proved that it was not carbonated hydrogen gas, or coal dissolved in inflammable air, as was generally conceived, but a combination of carbone and oxygen, and which has lately received the name of the gaseous oxide of carbone.

It differs from the carbonic acid, in containing a smaller proportion of oxygen, and these two gases, may be converted into each other at pleasure.

* Nicholson's Chemical Journal, April, 1805.

The most usual phenomena which accompany this combustion are, a blue flame, a whitish and suffocating vapour, and a strong, penetrating, and disagreeable smell.

The results of this combination vary according to the proportion in which these two principles enter into this same combination.

The sulphureous or the sulphuric acid may be at pleasure obtained from sublimed sulphur, or from crude sulphur, accordingly as a greater or less quantity of oxigene is combined with the sulphur, by means of combustion.

This air may be obtained,

First. By exposing most metallic calces and charcoal, to a red heat.

Secondly. By exposing to a high degree of heat, the carbonates of lime and barytes, mixed with the filings of zinc or iron.

Thirdly. By exposing moistened charcoal to a red heat, according to Morveau, Berthollet, Fourcroy, Thenart, Desormes, and Clement, as quoted by Thomson.

Fourthly. By mixing charcoal and the earthy carbonates, and submitting them to heat.

Fifthly. By passing carbonic acid repeatedly over red hot coal, or transmitting it over red hot iron wire. The iron wire will abstract a portion of oxigene from the carbonic acid, and convert it into the oxide of carbon.

I mixed 40 grs. of dry coal, with half an ounce of colcothar of vitriol, and put the mixture into a gun-barrel. Half an ounce of the oxide of copper, prepared by exposing the sulphate of copper to an intense heat, was placed over the charcoal and calx of iron. Upon exposing the gun-barrel to a high degree of heat, one hundred ounce measures of carbonic acid gas were procured, without any mixture of the oxide of carbone.

In this case, the carbone united with the oxigene of the colcothar of vitriol, and formed carbonic acid gas and oxide of carbone; but as this oxide of carbone passed over the calx of copper, it seized another portion of oxigene, and was converted into carbonic acid gas.

The gaseous oxide of carbone is lighter than atmospheric air, or carbonated hydrogen gas. It is fatal to animal life, and improper for combustion. When breathed for a few minutes, it produces giddiness and fainting. Neither heat, light, nor electricity have any effect upon it. It dissolves phosphorus. It is not affected by the alkalis. Exploded in the eudiometer of Volta with oxigene air, it is converted into the carbonic acid.

If four parts of oxygenated muriatic acid gas is mixed with one part of carbonic oxide gas, the oxigene of the oxymuriatic gas, will unite to the oxide of carbone, and form carbonic acid gas, and a substance similar to wax will make its appearance.

Oxide of carbone, mixed with sulphurated hydrogen gas, and passed through a red hot tube, will deposit sulphur, and sulphurated hydrogen gas, mixed with carbonic oxide gas, will remain.—*Am. Ed.*

When the current of air which maintains the combustion is rapid, the sulphur is carried, and deposited without any apparent alteration, into the internal part of the leaden chambers in which the oil of vitriol is made. If the current of air be rendered more moderate, the combination is somewhat more accurate; the sulphur is partly changed, and is deposited in a pellicle upon the surface of the water. This pellicle is flexible like a skin, and may be handled and turned over in the same manner. If the current be still less rapid, and the air be suffered to have a sufficient time to form an accurate combination with the sulphur, the result is sulphureous acid; which acid preserves its gaseous form at the temperature of the atmosphere, and may become liquid like water by the application of cold, according to the fine experiments of Mr. Monge. If the combustion be still slower, and the air be suffered to digest upon the sulphur a longer time, and with greater accuracy, the result is sulphuric acid: this last combination may be facilitated by the mixture of saltpetre, because this substance furnishes oxigene very abundantly.

Numerous experiments which I have made in my manufactory, to economize the saltpetre employed in the fabrication of oil of vitriol, have several times exhibited the results here mentioned.

All the processes which are capable of being adapted for extracting the sulphuric acid, are reducible to—1. The extraction of it from substances which contain it. 2. Its direct formation by the combination of sulphur and oxigene.

In the first case, the sulphures, or vitriolic salts of iron, copper, or zinc, and even those whose bases are clay and lime, according to Newman and Margraff, may be exposed to distillation. But these expensive processes are not very easy to be carried into execution; and accordingly they have been abandoned, to make room for others of greater simplicity.

In the second case, the oxigene may be presented to the sulphur in two forms; either in the state of gas, or in the concrete state.

1. The combustion of sulphur by oxygenous gas, is performed in large chambers lined with lead. The com-

bustion is facilitated by mixing about one-eighth of the nitrate of pot-ash with the sulphur. The acid vapours which fill the chamber are precipitated against its sides, and the condensation is facilitated by a stratum of water disposed on the bottom of the chamber. In some manufactories in Holland, this combustion is performed in large glass balloons with large mouths, and the vapours are precipitated upon water placed at the bottom.

In both cases when the water is sufficiently impregnated with acid, it is concentrated in leaden boilers, and rectified in glass retorts, to render it white, and to concentrate it sufficiently for the purposes of trade. The acid, when of a due strength, indicates sixty-six degrees, according to the aerometer of Mr. Baumé; and when it has not been carried to this degree, it is unfit for most of the uses for which it is intended. It cannot, for example, be employed in dissolving indigo; for the small quantity of nitric acid which it contains, unites with the blue of the indigo, and forms a green colour. I have ascertained this phenomenon by very accurate experiments; and I have been a witness to the failing of colours, and the loss of stuffs, in consequence of the imperfection of the acid.

2. When the oxigene in the concrete state is presented to the sulphur, it is then in combination with other bodies, which it abandons to unite with this last. This happens when the nitric acid is distilled from sulphur. Forty-eight ounces of this acid, at thirty-six degrees, distilled from two ounces of sulphur, afforded near four ounces of good sulphuric acid. This fact was known to Matte Lafaveur: but I pointed out all the phenomena and circumstances of the operation in 1781.

Sulphur may likewise be converted into sulphuric acid by means of the oxigenated muriatic acid.—*Encyclopédie Methodique*, tom. i. p. 370.

The sulphuric acid which is found disengaged in some places in Italy, appears likewise to arise from the combustion of sulphur. Baldassari has observed it in this state in a hollow grotto, in the midst of a mass of inerrustations deposited by the baths of Saint Philip, in Tuscany. He asserts that a sulphureous vapour continually arises in this grotto. He likewise found sulphureous and

vitriolic effervescences at St. Albino, near mount Pulciano, and at the lakes of Travale, where he observed the branches of a tree covered with concretions of sulphur and the oil of vitriol.—*Journal de Physique*, t. vii. p. 395.

O. Vandelli relates that, in the environs of Siena and Viterbo, sulphuric acid is sometimes found dissolved in water. Mr. (the commander) De Dolomieu affirms that he found it pure and crystallized in a grotto of mount Etna, from which sulphur was formerly obtained.

According to a first experiment of Mr. Berthollet, sixty-nine parts of sulphur with thirty-one parts of oxigene formed one hundred parts of sulphuric acid; and, according to a second experiment, seventy-two of sulphur and twenty-eight of oxigene formed one hundred parts of dry acid.

The various degrees of concentration of the sulphuric acid have caused it to be distinguished by different names, under which it is known in commerce. Hence the denominations of Spirit of Vitriol, Oil of Vitriol, and Glacial Oil of Vitriol, to express its degrees of concentration.

The sulphuric acid is capable of passing to the concrete state by the impression of intense cold.* Kunckel and Bohn have spoken of it; and Boerhaave says expressly “*Oleum vitrioli, summâ arte purissimum, summo frigore hiberno in glebas solidescit perspicuas; sed, statim ac acuties frigoris retunditor, liquescit et diffluit.*”—We are indebted to the Duke D’Ayen for some very valuable experiments upon the congelation of this acid; and Mr. De Morveau repeated them with equal success in 1782, and proved that this congelation may be effected at a degree of cold considerably less than what had been mentioned†.

I have already several times obtained beautiful crystals of sulphuric acid in flattened hexahedral prisms, terminated by an hexahedral pyramid; and my experiments have enabled me to conclude—1. That the very concentrated acid crystallizes more difficultly than that whose density lies between sixty-three and sixty-five. 2. That the proper degree of cold is from 1 to 3 degrees below

* See also the experiments of Mr. Kier. and the late experiments of Mr. Cavendish on the congelation of acids, in the *Philosophical Transactions*.

† This congelation is a phenomenon long since known.

O of Reaumur. The detail of my experiments may be seen in the volume of the Academy of Sciences of Paris for the year 1784.

The characters of the sulphuric acid are the following :

1. It is unctuous and fat to the touch, which has occasioned it to obtain the very improper name of Oil of Vitriol.

2. It weighs one ounce and seven gross in a bottle containing one ounce of distilled water.

3. It produces heat, when mixed with water, to such a degree as to exceed that of boiling water. If one end of a tube of glass be closed, and water poured into it, and the closed end of this tube be plunged into water, the water in the tube may be made to boil by pouring sulphuric acid into the external water which surrounds the tube.

4. It seizes with great avidity all inflammable substances ; and it is blackened and decomposed by this combination.

Stahl supposed the sulphuric acid to be the universal acid. He founded this opinion more especially upon the circumstance, that cloths soaked in a solution of alkali, and exposed to the air attracted an acid which combined with the alkali ; and formed a neutral salt, by him supposed to be of the nature of sulphate of potash, or vitriolated tartar. Subsequent and more accurate experiments have shewn that this aërial acid was the carbonic ; and the present state of our knowledge is such as permits us still less than ever to believe in the existence of an universal acid:

ARTICLE I.

Sulphate of Potash.

The sulphate of potash is described indifferently under the names of Arcanum Duplicatum, Sal de Duobus, Vitriolated Tartar, Vitriol of Potash, &c.

This salt crystallizes in hexahedral prisms, terminating in hexahedral pyramids, with triangular faces.

It has a lively and penetrating taste, and melts difficultly in the mouth.

It decrepitates on hot coals, becomes red-hot before it fuses, and is volatilized without decomposition.

It is soluble in sixteen parts of cold water, at the temperature of 60 degrees of Fahrenheit: and boiling water dissolves one-fifth of its weight.

100 grains contain 30.21 acid, 64.61 alkali, and 5.18 water. Most of the sulphate of potash used in medicine is formed by the direct combination of the sulphuric acid and potash, or the vegetable alkali: but that which is met with in commerce is produced in the distillation of aqua fortis, by the sulphuric acid;* this has the form of beautiful crystals, and is sold in the Comtat Venaissin at forty or fifty livres the quintal. The analysis of tobacco has likewise afforded me this sulphate.

Mr. Baumé proved to the Academy, in 1760, that the nitric acid, assisted by heat, is capable of decomposing the sulphate of potash. Mr. Cornette afterwards shewed that the muriatic acid possesses the same virtue; and I shewed, in 1780, that this acid may be displaced by the nitric acid, without the assistance of heat; though the sulphuric acid resumes its place when the solution is concentrated by heat.

ARTICLE II.

Sulphate of Soda.

This combination of the sulphuric acid and soda is still known under the names of Glauber's Salt, Sal Admirabile, Vitriol of Soda, &c. This salt crystallizes in rectangular octahedrons, of a prismatic or cuneiform figure, of which the two pyramids are truncated near their basis.

It has a very bitter taste, and easily dissolves in the mouth.

* When the sulphuric acid is added to nitre, to make the nitric acid, it unites with the potash of the nitre, and forms vitriolated tartar, while the acid is disengaged from its alkaline base.—*Am. Ed.*

It swells up upon heated coals, and boils, in consequence of the dissipation of its water of crystallization. After this water has been dispersed, there remains only a white powder, difficult of fusion, which is volatilized without decomposition by a strong heat.

By exposure to the air, it effloresces, loses its transparency, and is reduced to a fine powder.

Three parts of water, at 60 degrees of Fahrenheit's thermometer, dissolved one part of this salt; but boiling water dissolves its own weight.

100 grains of sulphate of soda contain 14 acid, 22 alkali and 64 water.

It is formed by the direct combination of the two principles which contain it; but the *tamarix gallica*, which grows on the sea coasts, contains so large a quantity, that it may be extracted to advantage. Nothing more is necessary for this purpose, than to burn the plant, and lixiviate the ashes. That salt which is sold in the south of France, in fine crystals, is prepared in this manner. It is very pure, and the price does not exceed thirty or thirty-five livres the quintal. This sulphate is likewise formed in our laboratories when we decompose the muriate of soda, or common salt, by the sulphuric acid.*

Potash dissolved by heat in a solution of sulphate of soda, precipitates the soda, and takes its place.†

* Glauber's salt may be made by decomposing the sulphate of ammoniac by common salt. The sulphuric acid of the sulphate of ammoniac will unite to the soda of the common salt, and form Glauber's salt, while the muriatic acid of the common salt will join to the ammoniac of the sulphate of ammoniac, and form *sal ammoniac*.

The sulphate of ammoniac may be made by the direct combination of the sulphuric acid and the ammoniac distilled from bones; or by digesting this ammoniac, which contains a considerable quantity of carbonic acid, or plaster of Paris, which is a sulphate of lime. By a double elective attraction, carbonate of lime and sulphate of ammoniac will be formed. The editor of this work published this process, in the *Columbian Magazine*, in the year 1791, and it is now carried into effect in France and England.

Glauber's salt is manufactured in immense quantities, from sea water, in the eastern parts of Massachusetts. It is said that twenty tons a year are made. *Medical Repository*, vol. ii. Hexadec. second. p. 449.—*Am. Ed.*

† One of the various methods of obtaining soda from sulphate of soda, is by adding potash, whereby the sulphuric acid is transferred to the vegetable alkali, and the soda is left uncombined. This generally answers in an æconomical point of view, as the price of

ARTICLE III.

Sulphate of Ammoniac.

The sulphate of ammoniac, commonly known by the name of Glauber's Secret Ammoniacal Salt, is very bitter.

It crystallizes in long flattened prisms with six sides, terminated by six-sided pyramids.

It cannot be obtained in well-formed crystals but by insensible evaporation.

It slightly attracts the humidity of the air.

potash is much lower than that of soda; and besides in the crystallized state in which the carbonate of soda is prepared for sale, water of crystallization forms a very large proportion of its composition.

Mr. Accum describes this process of transferring the alkali to be the following, when prepared in the large way:

Five hundred parts of sulphate of soda are put into an iron boiler with a sufficient quantity of water, and in another iron boiler by the side of the former are dissolved five hundred pounds of American potash, in about thirty pails full of water. When both solutions are boiling hot, the potash solution is laded into the boiler of sulphate of soda, the mixture strongly agitated, and briskly heated: when gently boiling, the whole liquor is laded into a cistern of wood, lined with sheet lead half an inch thick, and also containing slips of sheet lead two or three inches wide, suspended in the fluid, at intervals of about four inches from each other. In about three days, when the whole is quite cold, the uncrystallized liquor is let off, and a large mass of salt is found adhering to the slips of lead, and settled to the bottom of the cistern. This salt is chiefly a mixture of sulphate of potash and carbonate of soda. It is then washed in cold water, transferred into the boiler, and again dissolved in clear water, and evaporated briskly, till a strong pellicle appears on the surface. The liquor is then cooled till the hand can be borne in it, and the heat kept at that point as long as pellicles form on the surface, and drop down to the bottom. These pellicles are the sulphate of potash, separated by evaporation of the liquid, on account of its more difficult solubility in water than the soda.

The remaining liquid, which now contains little else than carbonate of soda, is laded out and suffered to crystallize, and then dried for sale. By this process about one hundred and thirty-six pounds of carbonate of soda is prepared from one hundred pounds of sulphate of soda, with the requisite proportion of potash. The smaller grained crystals are the purest; the larger masses of carbonate of soda still contain a considerable quantity of sulphate of potash.

It liquefies by a gentle heat, and rises over a moderate fire.

Two parts of cold water dissolve one of this salt; and boiling water dissolves its own weight, according to Fourcroy. The fixed alkalis, barytes, and lime, disengage the ammoniac from it.

The nitric and muriatic acids disengage the sulphuric acid.

The different substances of which we have treated are of considerable use in the arts and medicine.

The sulphureous acid is employed in whitening silk, and giving it a degree of lustre. Stahl had even combined it with alkali, and formed the salt so well known under the name of Stahl's Sulphureous Salt. This combination passes quickly to the state of sulphate, if it be left exposed to the air; as it speedily absorbs the oxigene which is wanting for that purpose.

The principal use of the sulphuric acid is in dying, in which art it serves to dissolve indigo, and carry it in a state of extreme division upon the stuffs to be dyed; it is likewise used by the manufacturers of Indiens, or silk and stuff mixtures, to carry off the preparation of these goods, wherein lime is used. The chemist makes great use of this acid in his analyses; and to separate other acids from their combination; such as the carbonic, the nitric, and the muriatic acids.

The sulphate of potash is known in medicine as an alterative, and is used in cases of lacteous coagulations. It is given in the dose of a few grains, and is even purgative in a greater dose.

The sulphate of soda is an effectual purgative in the dose of from four to eight gross, or drams. For this purpose it is dissolved in a pint of water.

CHAPTER III.

*Concerning the Nitric Acid.**

THE nitric acid, called Aqua Fortis, when diluted with water, in commerce, is lighter than the sulphuric. It usually has a yellow colour, a strong and disagreeable smell, and emits red vapours.† It gives a yellow colour to the skin, to silk, and to almost all animal substances with which it may come in contact. It dissolves and speedily corrodes iron, copper, zinc, &c. with the escape of a cloud of red vapours during the whole time its action lasts. It entirely destroys the colour of violets, which it reddens. It unites to water with facility; and the mixture assumes a green colour, which disappears when still further diluted.

This acid has been no where found in a disengaged state. It always exists in a state of combination; and it is from these combinations that the art of chemistry extracts it, to apply to our uses. The nitrate of potash, or common nitre, is the combination which is best known, and is likewise that from which we usually extract the nitric acid.

* Dr. Mitchell, of New-York, has properly considered this acid, as of animal origin, and as it is formed from putrid animal substance, he has proposed to call it the septic acid, from the Greek word *σπρω*, *putrefacio*.

If this nomenclature was adopted, we would have septon; instead of azote or nitrogene.

Septous gas; instead of azotic gas or nitrogene gas.

Gaseous oxide of septon; instead of gaseous oxide of azote or of nitrogene, or nitrous oxid.

Septic gas; instead of nitrous air.

Septous acid; instead of nitrous acid.

Septic acid; instead of nitric acid.

Septate, septite, &c.—*Am. Ed.*

† The red clouds are formed by the nitrous air, which the acid contains escaping, and uniting to the oxygenous portion of atmospheric air.—*Am. Ed.*

The process used in commerce to make aqua fortis, consists in mixing one part of saltpetre with two or three parts of red bolar earth. This mixture is put into coated retorts, disposed in a gallery or long furnace, to each of which is adapted a receiver. The first vapour which arises in the distillation is nothing but water, which is suffered to escape at the place of juncture, before the luting: and when the red vapours begin to appear, the phlegm which is condensed in the receiver is poured out; and the receiver, being replaced, is carefully luted to the neck of the retort. The vapours which are condensed, form at first a greenish liquor: this colour disappears insensibly, and is replaced by another which is more or less yellow. Some chemists, more especially Mr. Baumé, were of opinion that the earth acted upon the saltpetre by virtue of the sulphuric acid it contains. But not to mention that this principle does not exist in all the earths made use of, as Messrs. Macquer, De Morveau, and Scheele have proved, we know that pulverized flints equally produce the decomposition of saltpetre. I am therefore of opinion that the effect of these earths upon the salt ought to be referred to the very evident affinity of the alkali to the silex, which is a principal component part; and more especially to the slight degree of adhesion which exists between the constituent principles of nitrate of potash.

We decompose saltpetre in our laboratories by means of the sulphuric acid. Very pure nitrate of potash is taken, and introduced into a tubulated retort, placed in a sand bath, with a receiver adapted. All the places of junction are carefully luted; and as much sulphuric acid as amounts to half the weight of the salt is poured through the tubulure; and the distillation is proceeded upon. Care is taken to fit a tube into the tubulure of the receiver; the other end of which is plunged into water, to condense the vapours, and to remove all fear of an explosion.

Instead of employing the sulphuric acid, we may substitute the sulphate of iron, and mix it with saltpetre in equal parts. In this case the residue of the distillation, when well washed, forms the mild earth of vitriol made use of to polish glass.

Stahl and Kunckel have spoken of a very penetrating aqua fortis, of a blue colour, obtained by the distillation of nitre with arsenic.

Whatever precaution is taken in the purification of the saltpetre, and however great the attention may be which is bestowed upon its distillation, the nitric acid is always impregnated with some foreign acid, either the sulphuric or muriatic, from which it requires to be purified. It is cleared of the first by redistilling it upon very pure saltpetre, which retains the small quantity of sulphuric acid that may exist in the mixture.* It is deprived of the second by pouring into it a few drops of a solution of nitrate of silver. The muriatic acid combines with the silver, and is precipitated with it in the form of an insoluble salt. The fluid is then suffered to remain at rest, and is afterwards decanted from the precipitate or deposition. This acid, so purified, is known under the name of Aqua Fortis for Parting, Precipitated Nitrous Acid, Pure Nitric Acid, &c.

Stahl had considered the nitric acid as a modification of the sulphuric, produced by its combination with an inflammable principle. This opinion has been supported by several new facts, in a dissertation of Mr. Pietsch, crowned by the Academy of Berlin in 1749.

The experiments of the celebrated Hales led him still nearer to this conclusion, as his manipulations were successively employed upon the two constituent principles of the nitric acid. This celebrated philosopher had obtained ninety cubic inches of air from half a cubic inch of nitre; and he proceeded no further in his conclusions, than to assert that this air is the principal cause of the explosions of nitre.

The same philosopher relates that the pyrites of Walton, treated with equal quantities of spirit of nitre and water, produce an air which has the property of absorbing the fresh air, which may be made to enter the vessel. This great man, therefore, extracted successively the two principles of the nitric acid; and these capital experiments put Dr. Priestley in the road to the discoveries he has since made.

It was not however until the year 1776, that the analysis of the nitric acid was well known. Mr. Lavoisier, by distilling this acid from mercury, and receiving the

* Or by adding the nitrate of barytes to it. The sulphuric acid will unite with the barytes, and form sulphate of barytes.—*Am. Ed.*

several products in the pneumato-chemical apparatus, has proved that the nitric acid, whose specific gravity is to that of distilled water as 131607 to 100000, contains—

	oz.	gross.	grains.
Nitrous gas	1	7	$51\frac{1}{4}$
Oxygenous gas	1	7	$7\frac{1}{2}$
Water	13	—	—

By combining these three principles together the decomposed acid was regenerated.

The action of the nitric acid on most inflammable matters, consists in nothing more than a continual decomposition of this acid.

If the nitric acid be poured upon iron, copper, or zinc, these metals are instantly attacked with a strong effervescence; and a considerable disengagement of vapours takes place, which become of a red colour by their combination with the atmospheric air, but which may be retained and collected in a state of gas in the hydro-pneumatic apparatus. In all these cases the metals are strongly oxidized.

The nitric acid, when mixed with oils, renders them thick and black, converts them into charcoal, or inflames them, accordingly as the acid is more or less concentrated, or in a greater or less quantity.

If very concentrated nitric acid be put into an apothecary's phial, and be poured upon charcoal in an impalpable powder, and very dry, it sets it on fire instantly, at the same time that carbonic acid and nitrogeous gas are disengaged.

The various acids which are obtained by the digestion of the nitric acid on certain substances, such as the oxalic acid, or acid of sugar, the arsenical acid, &c. owe their existence merely to the decomposition of the nitric acid, the oxygen of which is fixed in combination with the bodies upon which the acid is distilled. The facility with which this acid is decomposed, renders it one of the most active, because the action of acids upon most bodies is a consequence of their own proper decomposition.

The characters of nitrous gas, which is extracted by the decomposition of the acid, are—1. It is invisible, or perfectly transparent. 2. Its specific gravity is rather less than that of atmospherical air. 3. It is unfit for respiration,

though the abbé Fontana pretends that he respired it without danger. 4. It does not maintain combustion. 5. It is not acid, according to the experiments of the Duke de Chaulnes. 6. It combines with oxigene, and reproduces the nitric acid.

But what is the nature of this nitrous gas? It was at first pretended that it consists of the nitric acid saturated with phlogiston. This system ought to have been abandoned as soon as it was proved that the nitric acid deposited its oxigene upon the bodies on which it acted; and that the nitrous gas was less in weight than the acid made use of. A capital experiment of Mr. Canvendish has thrown the greatest light on the subject. This chemist having introduced into a tube of glass seven parts of oxigenous gas obtained without nitrous acid, and three parts of nitrogene gas; or, by estimating these quantities in weight, ten parts of nitrogene to twenty-six of oxigene—and having caused the electric spark to pass through this mixture, perceived that its volume or bulk was greatly diminished, and succeeded in converting it into nitric acid. It may be presumed, from his experiment, that the acid is a combination of seven parts of oxigene, and three of nitrogene. These proportions constitute the ordinary nitric acid; but when a portion of its oxigene is taken away, it passes to the state of nitrous gas; so that nitrous gas is a combination of nitrogene gas, with a small quantity of oxigene.

Nitrous gas may be decomposed by exposing it to a solution of the sulphure of potash, or hepar of sulphur: the oxigene gas unites to the sulphur, and forms sulphuric acid, while the nitrogene gas remains behind in a state of purity.

Nitrous gas may likewise be decomposed by means of pyropliorus, which burns in this air, and absorbs the oxigenous gas.

The electric spark has likewise the property of decomposing nitrous gas. Mr. Van Marum has observed that three cubic inches of the nitrous gas are reduced by electricity to one cubic inch and three quarters: and that this residue no longer possessed any property of nitrous gas. Lastly, according to the experiments of Mr. Lavoisier, one hundred grains of nitrous gas contain thirty-two parts

nitrogene, and sixty-eight parts oxigene: according to the same chemist, one hundred grains of nitric acid contain seventy-nine and a half oxigene, and twenty and a half nitrogene; and this is the reason why nitrous gas should be employed in a less portion than nitrogene gas, to combine with the oxigene gas, and form the nitric acid.

These ideas upon the composition of the nitrous acid, appear to be confirmed by the repeated proofs we now have of the necessity of causing substances, which afford much nitrogene gas, to be presented to the oxigene gas, in order to obtain nitric acid.

The several states of the nitric acid may be clearly explained according to this theory:—1. The fuming nitrous acid is that in which the oxigene does not exist in a sufficient proportion; and we may render the whitest and the most saturated nitric acid fuming and ruddy, by depriving it of a part of its oxigene by means of metals, oils, inflammable substances, &c. or even by disengaging the oxigene by the simple exposition of the acid to the light of the sun, according to the valuable experiments of Mr. Berthollet.

The property which nitrous gas possesses, of absorbing oxigene to form the nitric acid, has caused it to be employed to determine the proportion of oxigene in the composition which forms our atmosphere. The abbé Fontana has constructed, on these principles, an ingenious eudiometer, the description and manner of using which may be seen in the first volume of Dr. Ingenhousz's experiments upon Vegetables.

Mr. Berthollet has very justly observed, that this eudiometer is inaccurate, or productive of deception—1. Because it is difficult to obtain nitrous gas constantly formed of the same proportions of nitrogene gas and oxigene; for they vary, not only according to the nature of the substances upon which the nitric acid is decomposed, but likewise accordingly as the solution of any given substance by the acid is made with greater or less rapidity. If the acid be decomposed upon a volatile oil, nothing but nitrogene gas can be obtained; if the acid act upon iron, and it be much concentrated, nitrogene gas only will be obtained, as I have observed, &c. 2. The nitric acid which is formed by the union of nitrous gas and ox-

igene, dissolves a greater or less quantity of nitrous gas according to the temperature, the quality of the air which is tried, the size of the eudiometer, &c. so that the diminution varies in proportion to the greater or less quantity of nitrous gas obtained by the nitric acid which is formed: consequently the diminution ought to be greater in winter than in summer, &c.

According to the experiments of Mr. Lavoisier, four parts of oxygenous gas are sufficient to saturate seven parts and one third of nitrous gas; whereas it is found that nearly sixteen parts of atmospheric air are required to produce the same effect: whence this celebrated chemist has concluded, that the air of the atmosphere does not in general contain more than one-fourth of oxygenous or respirable gas. Repeated experiments at Montpellier, upon the same principle, have convinced me that twelve or thirteen parts of atmospheric air are constantly sufficient to saturate seven parts and one-third of nitrous gas.

These experiments shew, to a certain degree of accuracy, the proportion in which vital air exists in the air which we respire; but they do not give us any information respecting the noxious gases which, when mixed with the atmospheric air, alter it, and render it unwholesome. This observation very much curtails the use of this instrument.

The combination of the oxygenous and nitrous gases always leaves an æriform residue, which Mr. Lavoisier estimated at about one thirty-fourth of the whole volume: it arises from the mixture of the foreign gaseous substances, which more or less affect the purity of the gases made use of.

ARTICLE I.

Nitrate of Potash.

The nitric acid, combined with potash, forms the salt so well known under the names of Nitre, Saltpetre, Nitre of Potash, &c.

This neutral salt is rarely the product of any direct combination of its two constituent parts. It is found

ready formed in certain places; and in this manner it is that the whole of the nitre employed in the arts is obtained.

In the Indies it effloresces on the surface of uncultivated grounds. The inhabitants lixivate these earths with water, which they afterwards boil and crystallize in earthen pots. Mr. Dombey has observed a great quantity of saltpetre near Lima, upon earths which serve for pasture, and which produce only gramineous plants. Mr. Talbot Dillon, in his travels into Spain, relates that one-third of all the grounds, and in the southern parts of that kingdom even the dust of the roads, contain saltpetre.*

Saltpetre is extracted in France from the ruins and plaster of old houses.

This salt exists ready formed in vegetables, such as parietaria and bugloss, &c. and one of my pupils, Mr. Virenque, has proved that it is produced in all extracts which are capable of fermenting.

The fermentation of saltpetre may be favoured, by causing certain circumstances to concur which are of advantage to its formation.

In the North of Europe the saltpetre-beds are formed with lime, ashes, earth of uncultivated grounds, and straw, which are stratified, and watered with urine, dunghill-water, and mother waters. These beds are defended by a covering of heath or broom. In the year 1775, the king caused a prize to be proposed by the Royal Academy of Sciences at Paris, to discover a method of increasing the product of saltpetre in France, and to relieve the people from the obligation of permitting the saltpetre-makers to examine their cellars, in order to discover and carry away saltpetre earths. Several Memoirs were offered on the subject, which the Academy united into a single volume; and these have added to our knowledge, by instructing us more especially concerning the nature of the matters

* There are vast caves in the state of Kentucky, which contain a yellow clay, which is strongly impregnated with the nitrates of lime and potash. Saltpetre caves are also met with in Upper Louisiana. Four men on a trading voyage lately discovered one several hundred miles up the Missouri. They spent five or six weeks in the manufacture of this article, and returned to St. Louis with four hundred weight of it. Medical Repository, vol. i.—Hexade 2. p. 396.—*Am. Ed.*

which favour the formation of nitre. It was known, for example, long since, that nitre is formed in preference near habitations, or in earths, impregnated with animal products: it was likewise known that, in general, the alkaline basis was afforded by the concurrence of a vegetable fermentation. Mr. Thouvenel, whose memoir was crowned, has proved that the gas which is disengaged by putrefaction, is necessary for the formation of nitre; that blood, and next to it urine, were the animal parts which were the most favourable to its formation; that the most minutely divided and the lightest earths were the most proper for nitrification; that the current of air must be properly managed, to fix upon these earths the nitric acid which is formed, &c.

It seems to me that Becher possessed a considerably accurate knowledge of the formation of nitre, as appears from the following passages:

“ *Hæc enim (vermes, muscæ, serpentes) putrefacta in terram abeunt prorsus nitrosam; ex qua etiam communi modo nitrum copiosum parari potest, sola elixatione cum aqua communi.*”—Phys. Subt. lib. i. S. V. t. i. p. 286.

“ *Sed et ipsum nitrum necdum finis ultimus putrefactionis est; nam cum ejusdem partes ignæ separantur, relinquæ in terram abeunt prorsum puram et insipidam, sed singulari magnetismo præditam novum spiritum aëreum attrahendi, rursusque nitrum fiendi.*”—Phys. Subt. S. V. t. i. p. 292.

From all the discoveries and observations which have been hitherto made, it follows that, in order to establish artificial nitre beds, it is necessary that animal putrefaction and vegetable fermentation should concur. The nitrogen gas, in its disengagement from the animal substances, combines with the oxigene, and forms the acid, which again unites with the alkali, whose formation is favoured by the vegetable decomposition.

When the manufacturer is in possession of saltpetre grounds, whether by the simple operations of nature or by the assistance of art, the saltpetre is extracted by the lixiviation of these earths; which lixivium is afterwards concentrated, and made to crystallize. In proportion as the evaporation goes forward, the marine salt, which al-

most always accompanies the formation of nitre, is precipitated. This is taken out with ladles, and set to drain in baskets placed over the boilers.

As a great part of the nitre has an earthy basis, and requires to be furnished with an alkaline basis to cause it to crystallize, this purpose is accomplished either by mixing ashes with the saltpetre earths, or by adding an alkali ready formed to the lixivium itself.

Nitre obtained by this first operation is never pure, but contains sea-salt, and an extractive and colouring principle, from which it must be cleared. For this purpose it is dissolved in fresh water, which is evaporated; and to which bullocks blood may be added, to clarify the solution. The nitre obtained by the second manipulation is known by the name of Nitre of the Second Boiling. If recourse be had to a third operation to purify it, it is then called Nitre of the Third Boiling.

The purified nitrate of potash is employed in delicate operations, such as the manufacture of gunpowder, the preparation of aqua fortis for parting, and the solution of mercury, &c. The saltpetre of the first boiling is used in those works where aqua fortis is made for the dyers. It affords a nitro-muriatic acid, which is capable of dissolving tin by itself.

The nitrate of potash crystallizes in prismatic octahedrons, which almost always represent six-sided flattened prisms, terminated by dihedral summits.

It has a penetrating taste followed by a sensation of coldness.

It is fusible upon ignited coals; and in this case its acid is decomposed. The oxigene unites with the carbone and forms the carbonic acid; the nitrogene gas and the water are dissipated; and it is this mixture of principles which has been known under the name of Clyssus of Nitre.

The distillation of the nitrate of potash affords twelve thousand cubic inches of oxigenous gas* for each pound of the salt.

Seven parts of water dissolve one of nitre, at sixty degrees of Fahrenheit; and boiling water dissolves its own weight of this salt.

* Mixed with azotic air.—*Ann. Ed.*

One hundred grains of the crystals of nitre contain thirty acid, sixty-three alkali, and seven water.

When a mixture of equal parts of nitre and sulphur are thrown into a red-hot crucible, a saline substance is obtained, which was formerly called *Sal Polycrest* of Glaser, and which has since been considered as *Sulphate of Potash*. If nitre be fused, and a few pinches of sulphur be thrown upon this salt infusion, and the whole be afterwards poured out or cast into plates, it forms a salt known by the name of *Crystal Mineral*.

A mixture of seventy-five parts of nitre, nine and a half of sulphur, and fifteen and a half of charcoal, forms gunpowder. This mixture is triturated from ten to fifteen hours, care being taken to moisten it from time to time. This trituration is usually performed by pounding mills, whose pestles and mortars are of wood. In order to give the powder the form proper to granulate it, it is passed through sieves of skin, whose perforations are of various sizes. The grained powder is then sifted, to separate the dust, and it is afterwards carried to the drying-house. Gun-powder for artillery, or cannon-powder, receives no other preparation; but it is necessary to glaze the powder which is intended for fowling. This last preparation is effected by putting it into a kind of cask which turns on an axis, and by whose movement the angles of the grains are broken, and their surfaces polished. We are indebted to Mr. Beaumé and the chevalier Darcy for a series of experiments, in which they have proved—

1. That good gunpowder cannot be made without sulphur.
2. That charcoal is likewise indispensably necessary.*
3. That the quality of gunpowder depends, *cæteris paribus*, upon the accuracy with which the mixture is made.
4. That the effect of powder is greater when simply dried than when it is granulated.†

* Coal for the manufactory of gunpowder, should be made in iron cylinders. The advantages of this process are so considerable, that the proportion of powder, used for the several pieces of ordnance in the navy and army of Great-Britain, has been reduced one third, when the coal was prepared in this manner.—*Am. Ed.*

† There are several methods of proving the goodness and strength of gunpowder. The following is the best: Lay two or three small

The effect of gunpowder depends upon the rapid decomposition which is made in an instant of a considerable mass of nitre, and the sudden formation of those gases which are the immediate product. Bernoulli, in the last century, ascertained the development of air by the deflagration of gunpowder: he placed four grains of powder in a recurved tube of glass, plunged the tube in water, and set fire to the gunpowder by means of the burning-glass; after the combustion the interior air occupied a larger space, so that the space abandoned by the water was such as would have contained two hundred grains of gunpowder.—Hist. de l'Académie des Sciences de Paris, 1696, t. ii. Memoire de M. Varignon sur le Feu et la Flamme.

The fulminating powder, which is made by the mixture and trituration of three parts of nitre, two of salt of tartar, and one of sulphur, produces effects still more terrible. In order to obtain the full effect, it is exposed in a ladle to a gentle heat; the mixture melts, a sulphureous blue flame appears, and the explosion takes place. Care must be taken to give neither too strong nor too slight a degree of heat. In either case the combustion of the principles takes place separately, and without explosion.*

heaps on separate pieces of clean writing paper, within a short distance of each other, and set fire to one of them; if the flame ascends quickly, with a good report, leaving the paper free from specks, and does not burn it into holes, and if the sparks fly off, setting fire to the adjoining heaps, the goodness of the ingredients, and proper manufacture of the powder, may be safely inferred; if otherwise, it is either badly made, or the ingredients are impure.—*Am. Ed.*

* When fulminating powder is heated, the sulphur unites to the potash, and forms sulphuret of potash or liver of sulphur, before detoning. Sulphurated hydrogen gas is disengaged from the sulphuret of potash, and oxygenous gas from the nitre. These two airs unite, and are inflamed by a part of the sulphur, which kindles by itself. They strike the atmospheric air with such rapidity, that it resists them in the same manner, as the sides of a gun barrel resist gunpowder.—*Am. Ed.*

ARTICLE II.

Nitrate of Soda.

This salt has received the name of Cubic Nitre on account of its form; but this denomination is not exact, because it affects a figure constantly rhomboidal.

It has a cool, bitter taste.

It slightly attracts the humidity of the air.

Cold water, at sixty [degrees of Fahrenheit's thermometer, dissolves one-third of its weight; and hot water scarcely dissolves more.

It fuses upon burning coals with a yellow colour; whereas common nitre affords a white flame, according to Margraff—24 Dissert. sur le Sel Commun, t. ii. p. 343.

100 grains of this salt contain 28.80 acid, 50.09 alkali, and 21.11 water.

It is almost always the product of art.*

* *Nitrate of Ammoniac.*

The best method of preparing this salt, is by the direct combination of the nitric acid, and the carbonate of ammoniac.

The nitrate of ammoniac varies very much in appearance, according to the temperature at which its solution is evaporated. If a heat of about 70° or 80°, and by slow cooling, it is obtained in six-sided prisms, terminated by six-sided pyramids. When the solution is evaporated at 212°, the crystals are channelled and have a fibrous texture, or they are formed of long soft elastic threads. When dried in a heat of about 300° it assumes the form of a white compact mass.

It has an acrid, bitter and disagreeable taste.

It is soluble in two parts of water, at a temperature of 60° of Fahrenheit,

It dissolves in half its weight of boiling water.

It deliquesces when exposed to the action of atmospheric air.

When the salt in the state of prismatic crystals, is heated, it becomes fluid, at a temperature below 300°, between 360° and 400°, it boils without decomposition, but when heated to 450 it is gradually decomposed, without losing its water of crystallization.

The compact nitrate of ammoniac undergoes no change, until it is exposed to a temperature higher than 260°. Between 275° and 300°, it sublimates slowly without decomposition. At 320°, it melts and is slowly decomposed.

When the salt undergoes decomposition at a temperature not exceeding 500°, it is converted into the dephlogisticated nitrous air of

CHAPTER IV.

*Concerning the Muriatic Acid.**

THIS acid is generally known by the name of Marine Acid, and it is still distinguished among artists by the name of Spirit of Salt.

* We are ignorant of the base of this acid. Professor Pachioni has asserted, that it may be formed by abstracting a portion of oxigene from water, by the Galvanic influence. We cannot adopt this opinion, until his experiments are confirmed by other chemists.—*Am. Ed.*

Dr. Priestley, the gaseous oxide of azote of the Dutch chemists, and the nitrous oxide of Mr. Davy.

When it is exposed to heat above 600°, it explodes in a violent manner, and is converted into nitrous acid, nitrous gas water and azotic gas ; hence it is called *nitrum flammans*.

When the nitrous oxide is formed from the nitrate of ammoniac, part of the oxigene of the nitric acid, of the nitrate of ammoniac, unites with the hydrogene of the ammoniac, and forms water ; another part of the oxigene of the acid unites to the azote of the ammoniac, and makes the nitrous oxid.

This oxide is always an artificial production.

A candle burns with a beautiful blue flame in this gas, and before its extinction the white inner flame becomes surrounded with a blue one.

This double flame arises from some of the vapour of the nitrous acid being mixed with the nitrous oxide, for it can be formed by plunging a taper in atmospheric air containing nitrous acid vapour, or into a mixture of nitrous oxide and azotic gas, through which the nitrous acid vapour is made to pass.

Phosphorus introduced into a jar of nitrous oxide in a state of active inflammation, burns in the same manner as in oxigene gas.

Sulphur introduced into it, burning with a feeble blue flame, is immediately extinguished, but when in a state of vivid inflammation, it burns with a rose coloured flame.

Iron wire placed in it with a small piece of wood fixed to it, when inflamed, burns in a vehement manner, and throws out bright scintillating sparks.

Nitrous oxide is readily absorbed by water, and may be expelled from it by means of heat.

It is lighter than the two preceding acids; it has a strong penetrating smell, resembling that of saffron, but

It has no acid or alkaline properties, as it does not change blue vegetable colours. It has a sweet taste. The alkalis have no action upon it. It explodes with a loud noise, when mixed with hydrogen gas. It is fatal to animal life.

Nitrous oxide when taken into the lungs, by breathing out and into a varnished silk bag or large bladder, in a dose of from four to six quarts, causes the most extraordinary effects. On some persons it produces the most agreeable sensations, and immoderate fits of laughter. It affects others with vertigo, dizziness, temporary madness, fainting, &c. When Mr. Humphrey Davy, to whom we are indebted for ascertaining the effects of this wonderful agent, breathed seven quarts of it, muscular motions were produced to a certain extent; sometimes he manifested his pleasure by stamping or laughing, and at other times, by dancing round the room and vociferating. At another time, having breathed nine quarts of the air, he first lost the perception of external things, and a vivid and intense recollection of some former experiments, passed through his mind, so that he called out, "WHAT AN AMAZING CONCATENATION OF IDEAS!"

When he breathed twenty quarts, a thrilling sensation from the chest to the extremities, was almost immediately produced. By degrees the pleasurable sensations were increased; he lost all connection with external things, trains of vivid visible images passed through his mind, and were connected with words in such a manner, as to produce perceptions perfectly novel. He supposed that he existed in a world of newly connected and newly modified ideas. He theorized and imagined that he made discoveries. Upon waking from this semi-delirious trance, indignation and pride were the first feelings produced, by the sight of the persons about him. His emotions were enthusiastic and sublime, and he exclaimed with a loud voice, "NOTHING EXISTS BUT THOUGHTS! THE UNIVERSE IS COMPOSED OF IMPRESSIONS, IDEAS, PLEASURES, AND PAINS." After this, he expressed his pleasure, by laughing and stamping.

Mr. Tobin having taken two quarts into his lungs, laughed, staggered, threw himself into a variety of theatrical attitudes, traversed the laboratory with a quick step, and his mind was elevated to a most sublime height.

Mr. Wedgwood had six quarts administered to him, and as soon as he had made two or three inspirations, he felt himself much affected, and his respiration hurried, which effect increased rapidly, until he became, as it were, intranced, when he threw the bag from him, and kept breathing on furiously with an open mouth, and holding his nose with his hand, having no power to take it away, although aware of the ridiculousness of his situation. He had a strong inclination to make antic motions with his hand and feet. When the first strong sensations went off, he felt, as it were, lighter than the atmosphere, and as if he was going to mount to the top of the room.

infinitely more pungent ; it emits white vapours when it is concentrated ; it precipitates silver from its solution in

Mr. George Burnet felt a general swell of sensations, vivid, strong, and inconceivably pleasurable, which mounted so fast, that had he not desisted to breathe the gas, he would have fainted from ecstasy.

Southey, the poet, upon breathing the gas, exclaimed, "*The air of the highest possible of all heavens, must consist of this gas.*"

In the year 1802, the editor of this work attempted to prepare a large quantity of the nitrous oxide, from the nitrate of ammoniac, made by decomposing the nitrate of potash by the sulphate of ammoniac, and by adding the nitric acid to sal ammoniac.

A great number of gentlemen, belonging to his chemical class, who intended to breathe the gas, were present in the morning, when he was filling his air holders with it, and saw all the operations going forwards.

In the afternoon being at his laboratory at two o'clock, the air was examined and found to be extremely impure, having made use of too great a degree of heat in generating it.

Expecting the gentlemen at three o'clock, the impure air was thrown away, and the air holders filled with atmospheric air.

This air was breathed by a variety of persons, under the impression that it was the nitrous oxide, and the greater part of them were affected with quickness of pulse, dizziness, vertigo, tinnitus aurium, difficulty of breathing, anxiety about the breast, &c.

The following is a letter received from one of the gentlemen:

"The nitrous oxide produced no sensible effect, for perhaps the space of a minute, after I began to breathe it. Soon after I was affected with a tinnitus aurium, which affected the sense of hearing, in the same manner as water, in a state immediately preceding ebullition does. At the same time, I had a sensation similar to that produced by swinging ; afterwards a difficulty of breathing gradually came on, which at length necessitated me to discontinue the respiration of the air. The difficulty of breathing, and the tinnitus then soon subsided. But the peculiar sensation in my breast, continued some time longer, which was succeeded by slight nausea, which continued six or eight hours.

A short account of the effects of the atmospheric air, was sent to Dr. Mitchell, who published it in the Medical Repository of New-York, vol. v. p. 461.

For many years after this, not seeing the experiments of Mr. Humphrey Davy, on this subject confirmed by other chemists, I believed that the influence of the imagination, caused all the effects, ascribed to the nitrous oxide.

In the winter of 1806, having prepared a quantity of this gas, extremely pure, from the nitrate of ammoniac, made by the direct combination of the nitric acid and the carbonate of ammoniac, two quarts of it were administered to Mr. Henry Latrobe, fourteen years of age, who breathed it in a very fair manner. In one minute he was affected in a most violent manner. He walked up and down the laboratory with a quick step, elevating one leg after the other, and

the form of an insoluble salt, &c. This acid has no where been found disengaged; and, to obtain it in this state, it

then suddenly throwing it down on the ground. He laughed immoderately and convulsively, the tears rolled down his cheeks in large drops, and he frothed at the mouth.

Witnessing these effects, and knowing the impossibility of counterfeiting such symptoms, I immediately resolved to try the effects of the gas on other persons, in doses of two and four quarts.

Mr. J. D. Maclean upon breathing the gas, fainted away, and recovered in about three minutes.

Mr. George Thornton looked wild, jumped over a high bench, and the effect suddenly ceased. Mr. Martin raised his hands above his head, and jumped about the room.

Mr. Pope placed his arms a kimbo, and surveyed the audience with great contempt.

Mr. William Barton was very much deranged; he ran about the laboratory, bellowed like a mad bull, and struck at every person near him. A week after, the gas being administered to him a second time, produced the same effect.

He felt a great increase of strength after recovering from the effects of the air.

It was with much difficulty I could separate the mouth piece of the bladder from his mouth.

Mr. N. S. Allison fainted, but recovered in a few minutes. Upon breathing the air, seven days afterwards, the same effect was produced.

Mr. Thomas Prioleau exclaimed "*I am in heaven, ye gods, stars, comets, meteors, Mahomet's a jackass, the elysian fields are hell compared with this,*" and then fainted.

Mr. Robert Patterson was affected with violent laughter.

Mr. Samuel Jackson in the same manner.

Mr. Peter Curtis laughed very heartily.

A week after, having a very large air holder, filled with atmospheric air, along side of two others, containing nitrous oxide, he breathed the atmospheric air, but no effect was produced.

Mr. Gerard Snowden fainted, but soon recovered.

Mr. William Handy laughed and fainted.

Mr. William Tyler fainted and recovered in three minutes. Seven days afterwards, trying the air, a second time, the same effect was produced.

Mr. Cornelius Dupont laughed and fainted. Baron John de Bretton experienced pleasurable sensations.

Mr. Benjamin Kugler laughed. Upon giving him atmospheric air, a week after this, he immediately knew the difference in the gases, and it produced no effect.

Mr. Thomas Lewis was very much enraged. He caught me by the collar, pulled at my cravat, tore my coat, run about the room, and struck at every person near him.

Mr. Evans breathed atmospheric air.

It produced no effect.

is necessary to disengage it from its combinations. Common salt is usually employed for this purpose.

The spirit of salt of commerce is obtained by a process little differing from that which is used in the extraction of aqua fortis. But as this acid adheres more strongly to its basis, the product is very weak, and only part of the marine salt is decomposed.

Flints pulverized and mixed with this salt, do not separate the acid. Ten pounds of flints in powder, treated by a violent fire with two pounds of the salt, did not afford me any other product than a mass of the colour of litharge. The fumes were not perceptibly acid. If clay, which has once served to decompose marine salt, be mixed with a new quantity of the same salt, it will not decompose an atom of it, even though the mixture be moistened and formed into a paste. These experiments have been se-

Mr. Wharton after fairly breathing four quarts of the gas, was beginning to be affected. He called out in a rapid manner, "*Give me another bottle, give me another bottle.*"

The nitrous oxide was tried by fifteen other persons, without producing any effect. Some of them took it into their lungs very fairly, others were frightened, and mixed it with the air of the atmosphere.

I am now convinced the gas produces all the effects ascribed to it, by the justly celebrated Mr. Davy; and I am happy in having this opportunity of confirming his experiments.

The following letter on this subject, was received from professor Silliman, of Yale college, Connecticut.

I have lately given the nitrous oxide a full and fair trial, and the result has been such as to confirm in the most satisfactory manner, Mr. Davy's account of the effects of this wonderful agent.

In my own case, after only two inspirations, I felt a momentary loss of distinct thought, then sensations of such pure and vehement delight, tingling through every fibre of my frame, to the extremities of my toes and fingers, that after failing in an attempt to express to my friends by articulate words the pleasure I felt, I demonstrated it by leaping up and down, stamping on the floor, and loud convulsive laughter.

One of our gravest citizens, a man of thirty-eight or forty years of age, was made to caper about like a monkey, with all the extravagant gestures of a tragedian, and the grimaces of a Harlequin. Some effect was produced on all who breathed the gas, and the full effect was manifested, in six instances out of eight. One of these took place before the class and many spectators, and was so marked as to banish every doubt. Six or eight quarts breathed into and out of a silk bag, will always I believe produce the effect.—*Am. Ed.*

veral times repeated in my manufactory, and have constantly exhibited the same results.

The sulphate of iron, or martial vitriol, which so easily disengages the nitric acid, decompose marine salt; but very imperfectly.

The impure soda known in France by the name of Blanquette, and in which my analysis has exhibited twenty-one pounds of common salt out of twenty-five, scarcely affords any muriatic acid when it is distilled with the sulphuric acid; but it affords abundance of sulphureous acid. Mr. Berard, the director of my manufactory attributed these results to the coal contained in this soda, which decomposed the sulphuric acid. He therefore calcined the blanquette to destroy the charcoal: and then he found he could treat it in the same manner as common salt, and with the same success.

The sulphuric acid is usually employed to decompose marine salt. My method of proceeding consists in drying the marine salt, pounding it, and putting it into a tubulated retort placed upon a sand bath. A receiver is adapted to the retort, and afterwards two bottles, after the manner of Woulfe, in which I distribute a weight of distilled water equal to that of the marine salt made use of. The joinings of the vessels are then luted, but with the greatest caution; and when the apparatus is thus fitted up, a quantity of sulphuric acid is poured through the tubulure equal to half the weight of the salt. A considerable ebullition is immediately excited; and when this effervescence is slackened, the retort is gradually heated, and the mixture made to boil.

The acid is disengaged in the state of gas; and mixes rapidly with the water, in which it produces a considerable degree of heat.

The water of the first bottle is usually saturated with the acid gas, and forms a very concentrated and fuming acid; and though the second is weaker, it may be carried to any desired degree of concentration, by impregnating it with a new quantity of the gas.

The ancient chemists were divided respecting the nature of the muriatic acid. Becher supposed it to be the sulphuric acid modified by his mercurial earth.

This acid is susceptible of combining with an additional dose of oxigene; and, what is very extraordinary, it becomes more volatile in consequence of this additional quantity; whereas the other acids appear to acquire a greater degree of fixity in the same circumstances. It may even be said, that its acid virtues become weaker in this case, since its affinities with alkalis diminish; and it is so far from reddening blue vegetable colours, that it destroys them.

Another phenomenon not less interesting, which is presented to us by this new combination, is, that though the muriatic acid seizes the oxigene with avidity, yet it contracts so weak an union with it, that it yields it to almost all bodies, and the mere action of light alone is sufficient to disengage it.

It is to Scheele that we are indebted for the discovery of the oxigenated muriatic acid. He formed it in the year 1774, by employing the muriatic as a solvent for manganese. He perceived that a gas was disengaged, which possessed the distinctive smell of aqua regia; and he was of opinion that in this case the muriatic acid abandoned its phlogiston to the manganese; in consequence of which notion he called it the Dephlogisticated Marine Acid. He took notice of the principal and truly astonishing properties of this new substance; and all chemists since his time have thought their attention well employed in examining a substance which exhibits such singular properties.

To attract this acid, I place a large glass alembic of one single piece upon a sand bath. To the alembic I adapt a small receiver; and to the receiver three or four small bottles nearly filled with distilled water, and arranged according to the method of Woulfe. I dispose the receiver and the bottles in a cistern, the places of junction being luted with fat lute, and secured with rags soaked in the lute of lime and white of egg. Lastly, I surround the bottles with pounded ice. When the apparatus is thus disposed, I introduce into the alembic half a pound of manganese of Ceyennes, and pour upon it, at several repetitions, three pounds of fuming muriatic acid. The quantity of acid which I pour at once is three ounces; and at each

time of pouring a considerable effervescence is excited. I do not pour a new quantity until nothing more comes over into the receivers. This method of proceeding is indispensably necessary, when the operator is desirous of making his process with a definite quantity of the materials. For if too large a quantity of acid be poured at once, it is impossible to restrain the vapours; and the effervescence will throw a portion of the manganese into the receiver. The vapours which are developed by the affusion of muriatic acid are of a greenish yellow colour; and they communicate this colour to the water when they combine with it. When this vapour is concentrated by means of the ice, and the water is saturated with it, it forms a scum at the surface, which is precipitated through the liquid, and resembles a congealed oil. It is necessary to assist the action of the muriatic acid by means of a moderate heat applied to the sand bath. The secure luting of the vessels is also an essential circumstance; for the vapour which might escape is suffocating, and would not permit the chemist to inspect his operation closely. It is easy to discover the place where it escapes through the lutes, by running a feather dipped in volatile alkali over them; the combination of these vapours instantly forms a white cloud, which renders the place visible where the vapour escapes. An excellent Memoir of Mr. Berthollet, published in the *Annales Chimiques*, may be consulted upon the oxigenated muriatic acid.

The same oxigenated muriatic acid may be obtained by distilling, in a similar apparatus, ten pounds of marine salt, three or four pounds of manganese, and ten pounds of sulphuric acid.

Mr. Reboul has observed that the concrete state of this acid is a crystallization of the acid, which takes place at three degrees of temperature below the freezing point of Reaumur. The forms which have been observed are those of a quadrangular prism truncated very obliquely, and terminated by a lozenge. He has likewise observed hollow hexahedral pyramids on the surface of the liquor.

To make use of the oxigenated acid in the arts, and in order to concentrate a greater quantity in a given volume of water, the vapour is made to pass through a solution of alkali. A white precipitate is at first formed in the liquor;

but a short time afterwards the deposition diminishes, and bubbles are disengaged, which are nothing but the carbonic acid. In this case two salts are formed, the oxigenated muriate, and the ordinary muriate. The mere impression of light is sufficient to decompose the former, and convert it into common salt. This lixivium contains, indeed, the oxigenated acid in a stronger proportion. The execrable smell of the acid is much weakened. It may be employed for various uses with the same success, and with great facility; but the effect is very far from corresponding with the quantity of oxigenated acid which enters into this combination, because the virtue of a great part is destroyed by its union with the alkaline basis.

The oxigenated muriatic acid has an excessively strong smell. It acts directly on the larynx, which it stimulates, excites coughing, and produces violent head-aches.

Its taste is sharp and bitter. It speedily destroys the colour of tincture of turnsol. But it appears that the property which most oxigenated substances possess, of reddening blue colours, arises only from the combination of oxigene with the colouring principles; and that, when this combination is very strong and rapid, the colour is destroyed.

The oxigenated muriatic acid with which a solution of caustic alkali is saturated, affords, by evaporation in vessels secluded from the light, common muriate and oxigenated muriate. This last detonates upon charcoal; is more soluble in hot than in cold water; crystallizes, sometimes in hexahedral laminæ, and oftener in rhomboidal plates. These crystals have an argentine brilliancy, like mica. Its taste is faint; and its crystals, when they are dissolved in the mouth, produce a sensation of coolness resembling that of nitre.*

* The taste of oximuriate of potash is cooling, austere, and disagreeable. It phosphoresces when rubbed smartly, or rather emits a number of sparks of fire.

It is soluble in seventeen parts of water, at the temperature of 60° , and in $2\frac{1}{2}$ parts of boiling water. It is not altered by exposure to the air. It exhibits astonishing properties, when mixed with combustible bodies. It is decomposed by all these substances, and the decomposition is generally attended with violent detonations.

It cannot be kept in contact with sulphur, as it detonates spontaneously with this substance. If the sulphuric acid be poured upon a

Mr. Berthollet has ascertained, by delicate experiments that the oxigenated muriatic acid which exists in the oxigenated muriate of potash, contains more oxigene than an equal weight of oxigenated muriatic acid dissolved in water; and this has led him to consider the oxigenated acid combined in the muriate as being superoxigenated. He considers the common muriatic gas with relation to the oxigenated muriatic gas, the same as the nitrous gas or sulphureous gas with respect to the nitric and sulphuric acids. He pretends that the production of the simple muriate and the oxigenated muriate in the same operation, may be compared to the action of the nitric acid, which in many cases produces nitrate and nitrous gas. Hence he has considered the muriatic acid as a pure radical, which, combined with a greater or less quantity of oxigene, forms either simple muriatic acid gas, or the oxigenated muriatic gas.

The oxigenated muriates of soda do not differ from those of potash, but in being more deliquescent and soluble in alcohol, like all the salts of this nature.

mixture of this salt and sulphur, charcoal, or the metals, or oil of turpentine, or almost any combustible, a very brilliant flame is emitted.

When it is triturated in a mortar, with cotton cloth, small repeated explosions are heard, similar to the crack of a whip, and if the cotton be dry and warm, it sometimes takes fire.

Mr. Robert mentions a variation in the method of making the detonations with oximuriate of potash, and various combustible substances, which form a number of easy and amusing experiments. It is known that if a quantity of sulphuric acid is poured on these mixtures, they will suddenly inflame. Mr. R. finds the same effect when they are merely touched with a rod of glass dipped in the acid. In this manner he inflamed three parts of the oximuriate, and one of sulphur; three of the same salt, half a part of charcoal, and as much sulphur; equal parts of the salt and regulus of antimony; equal parts of the salt and ore of antimony; equal parts of the salt and kermes mineral; equal parts of the salt and arsenic; three parts of the salt and one of sugar; one and a half of the salt and three of gunpowder; and masses made with alcohol, olive oil and the oximuriate. A pistol was fired by being first loaded in the usual way, the pan filled with a mixture of gunpowder and the oximuriate, and then touched with the sulphuric acid. The following is a very entertaining experiment given by the same: Fill a bladder with hydrogen gas, furnished with a brass tube; wet the end of the tube with sulphuric acid, sprinkle the moistened end with oximuriate of potash in fine powder, and at the same moment press the bladder; the hydrogen gas, in passing through, will be inflamed, the moment it touches the acid salt, as if by a spark of electricity. (*Annales de Chimie*, tom. 44.) —*Am. Ed.*

The oxygenated muriate of potash gives out its oxigene in the light, and by distillation as soon as the vessel is heated to redness. One hundred grains of this salt afford seventy-five cubic inches of oxigenous gas reduced to the temperature of twelve degrees of Reaumur. This air is purer than the others, and may be employed for delicate experiments, the oxygenated muriate of potash, when crystallized, does not trouble the solutions of nitrate of lead, of silver, or of mercury.

Mr. Berthollet has fabricated gunpowder, by substituting the oxygenated muriate instead of saltpetre. The effects it produced were quadruple. The experiment in the large way, which was made at Essone, is but too well known, by the death of Mr. Le Tors and Mademoiselle Chevraud. This powder exploded the moment the mixture was triturated.

The oxygenated muriatic acid whitens thread and cotton. For this purpose the cotton is boiled in a weak alkaline lixivium; after which the stuff is wrung out, and steeped in the oxygenated acid. Care is taken to move the cloth occasionally in the fluid, and to wring it out. It is then washed in a large quantity of water, to deprive it of the smell with which it is impregnated.

I have applied this known property to the whitening of paper and old prints: by this means they obtained a whiteness which they never before possessed. Common ink disappears by the action of this acid; but printers' ink is not attacked by it.

Linen and cotton cloths, and paper, may be bleached by the vapour of the oxygenated marine acid. I have made some experiments in the large way, which have convinced me of the possibility of applying this method to the arts. The memoir in which I have given an account of my experiments, will be printed in the volume of the Academy of Paris for the year 1787.

The oxygenated muriatic acid thickens oils; and oxides metals to such a degree, that this process may be advantageously used to form verditer.

The oxygenated muriatic acid dissolves metals without effervescence; because its oxigene is sufficient to oxide them without the necessity of the decomposition of water and consequently of the disengagement of gas.

This acid precipitates mercury from its solutions, and converts it into the state of corrosive sublimate.

It converts sulphur into sulphuric acid, and instantly deprives the very black sulphuric acid of its colour.

When mixed with nitrous gas, it passes to the state of muriatic acid, and converts part of the gas into nitric acid.

When exposed to light, it affords oxygenous gas, and the muriatic acid is regenerated.

The muriatic acid acts very efficaciously upon metallic oxides, merely in consequence of its becoming oxygenated; and in this case it forms with them salts, which are more or less oxygenated.

ARTICLE I.

Muriate of Potash.

This salt is still distinguished by the name of Febrifuge salt of Sylvius.

It has a disagreeable strong bitter taste.

It crystallizes in cubes, or in tetrahedral prisms.

It decrepitates upon coals; and when urged by a violent heat it fuses, and is volatilized without decomposition.

It requires three times its weight of water, at the temperature of sixty degrees of Fahrenheit, for its solution.

It is subject to scarcely any alteration in the air.

One hundred grains of this salt contain 29.68 acid, 63.47 alkali, and 6.85 water. It is frequently met with, but in small quantities, in the water of the sea, in plaster, in the ashes of tobacco, &c. The existence of this salt in the ashes of tobacco might with justice have surprised me, as I had reason to expect the muriate of soda which is employed in the operation called watering. Was the soda metamorphosed into potash by the vegetable fermentation? This may be determined by direct experiments.

ARTICLE II.

Muriate of Soda.

The received names of Marine Salt, Common Salt, and Culinary Salt, denote the combination of muriatic acid with soda.

This salt has a penetrating but not bitter taste. It decrepitates on coals, fuses, and is volatilized by the heat of a glass-maker's furnace, without decomposition.

It is soluble in 2.5 times its weight of water, at sixty degrees of Fahrenheit's thermometer.

One hundred grains of this salt contain 33.3 acid, 50 of alkali, and 16.7 of water.

It crystallizes in cubes. Mr. Gmelin has informed us that the salt of the salt lakes in the environs of Sellian on the banks of the Caspian sea, forms cubical and rhomboidal crystals.

Mr. De Lisle observes, that a solution of marine salt, left to insensible evaporation during five years by Mr. Rouelle, had formed regular octahedral crystals resembling those of alum.

Marine salt may be obtained in octahedrons, by pouring fresh urine into a very pure solution of fresh salt. Mr. Berniard is convinced that this addition changed only the form of the salt, without altering its nature.

Common salt is found native in many places. Catalonia, Calabria, Switzerland, Hungary, and Tyrol possess mines, which are more or less abundant. The richest salt mines are those of Wieliczka in Poland. Mr. Berniard has given us a description of them in the *Journal de Physique*; and Mr. Macquart, in his *Essays on Mineralogy*, has added interesting details concerning the working of these mines.*

Our salt springs in Lorraine and Franche-comté, and some indications afforded by Bleton, have appeared suf-

* There are two mountains of common salt in Russia near Astracan; several in the kingdom of Tunis and Algiers, in Africa; and a number in Asia. It is said there is a mountain of solid rock salt,

sufficient motives to Mr. Thouvenel to presume that salt mines exist in our kingdom. This chemist expresses himself in the following manner:

“At the distance of two leagues from Saverne, between the village of Huetenhausen and that of Garbourg, in a lofty mountain called Penserpereh, there are two great reservoirs of salt water; the one to the east at the head of a large deep and narrow valley, which is called the great Limerthaal; the other to the west, upon the opposite slope, towards Garbourg. They communicate together by five small streams, which are detached from the upper reservoir, and unite in the lower one. From these two salt reservoirs flow two large streams; the upper runs into Franche-comté, and the lower into Lorraine, where they supply the well-known salt works.”

The waters therefore flow to the distance of seventy leagues from the reservoir.*

Salt mines appear to owe their origin to the drying up of vast lakes. The shells and madrepores found in the immense mines of Poland are proofs of marine depositions. There are likewise some seas in which the salt is so abundant, that it is deposited at the bottom of the water; as appears from the analysis of the water of the lake Asphaltites, made by Messrs. Macquer and Sage.

This native salt is often coloured; and as in this state it possesses considerable brilliancy, it is called Sal-gem. It almost always contains an oxide of iron, which colours it.

As these salt mines are neither sufficiently abundant to supply the wants of the inhabitants of the globe, nor dis-

without any trees or shrubs on it, one thousand miles up the river Missouri. This mountain is one hundred and eighty miles long, and forty-five miles wide.

At Cordova, in the province of Catalonia in Spain, there is a mountain of salt, between four and five hundred feet in height, and three miles in circumference.

* Salt springs, which abound in common salt, are found in the North-Western Territory of the United States, near the lakes in Canada; upon the waters of the rivers Ohio, Kentucky, &c.

Dr. Benjamin De Witt has given an account of the Onondaga salt springs, which may be seen in the Transactions of the Agricultural Society of New-York, vol. i. The strongest of these springs contain about half a pound of salt to a gallon of water.—*Am. Ed.*

tributed with that uniformity as to permit all nations to have ready recourse to them, it has been found necessary to extract the salt from the water of the sea. The sea does not contain an equal quantity in all climates: Ingenhousz has shewn us that the northern seas contain less than the southern. Marine salt is so abundant in Egypt, that, according to Hasselquist, a fresh-water spring is a treasure which is secretly transmitted from father to son.

The method of extracting the water of the sea varies according to the climates.

1. In the northern provinces, the salt sands of the sea coasts are washed with the least possible quantity of water, and the salt is obtained by evaporation.—See the description of this process by Mr. Guettard.

2. In very cold countries, salt water is concentrated by freezing, and the residue is evaporated by fire.—See Wallerius.

3. At the salt springs of Lorraine and Franche-comté, the water is pumped up, and suffered to fall upon heaps of thorns, which divide it, and cause a part to evaporate. The farther concentration is effected in boilers.

4. In the southern provinces, at Peccais, at Peyrat, at Cette, and elsewhere, the extraction is begun by separating a certain quantity of water from the general mass of the sea, which is suffered to remain in square spaces, called *Partenemens*. For this purpose it is necessary to have sluices which may be opened and shut at pleasure, and to form surrounding walls which prevent all communication with the sea, except by means of these gates. It is in the *partenemens* that the water goes through the first stage of evaporation; and when it begins to deposite its salt, it is raised by bucket wheels to other square compartments, called *Tables*, where the evaporation finishes.

The salt is heaped together, to form the *cammelles*; in which state it is left for three years, in order that the deliquescent salts may flow out of it; and, after this interval of time, it is carried to market.

Exertions and inquiries have long since been made to discover a cheap method of decomposing marine salt, to obtain the mineral alkali at a low price, which is of such extensive use in the manufactures of soap, glass, bleach-

ing, &c. The processes hitherto discovered are the following;

1. The nitric acid disengages the muriatic acid, and forms nitrate of soda, which may be easily decomposed by detonation.

2. Potash displaces the soda, even in the cold, as I found by experiment.

3. The sulphuric acid forms sulphate of soda by decomposing the marine salt; the new salt, when heated with charcoal, is destroyed; but a sulphure of soda, or liver of sulphur, is formed, which is difficult to be entirely separated; and this process does not appear to me to be economical. The sulphure may likewise be decomposed by the acetite of barytes, and the soda afterwards obtained by calcination of the azetite of soda.

4. Margraff tried in vain to accomplish this purpose, by means of lime, serpentine, iron, clay, &c. He adds, that if common salt be thrown upon lead heated to redness, the salt is decomposed, and muriate of lead is formed.

5. Scheele has pointed out the oxides of lead for the decomposition of common salt. If common salt be mixed with litharge, and made into a paste, the litharge gradually loses its colour, and becomes converted into a white matter, from which the soda may be extracted by washing. It is by processes of this kind that Turner extracts it in England; but this decomposition never appeared to me to be complete, unless the litharge was employed in a proportion quadruple to that of the salt. I have observed that almost all bodies are capable of alkalinizing marine salt, but that the absolute decomposition is very difficult.

6. Barytes decomposes it likewise, according to the experiments of Bergmann.

7. The vegetable acids, combined with lead, may likewise be used to decompose common salt. When these salts are mixed, a decomposition takes place: the muriate of lead falls down; and the vegetable acid, united to the soda, remains in solution. The vegetable acid may be dissipated by evaporation and calcination; and the alkali remains disengaged.

Marine salt is more especially employed at our tables, and in culinary purposes. It removes and corrects the insipidity of our food, and at the same time facilitates digestion. It is used in a large proportion to preserve flesh from putrefaction; but in a small dose it hastens that process, according to the experiments of Pringle, Macbride, Gardane, &c.

ARTICLE III.

Muriate of Ammoniac.

Of all the combinations of ammoniac this is the most interesting, and the most generally used. It is known by the name of Sal Ammoniac.

This salt may be directly formed by decomposing the muriate of lime by the means of ammoniac, as Mr. Baumé has practised at Paris. But almost all the sal ammoniac which circulates in commerce is brought to us from Egypt, where it is extracted by distillation from soot, by the combustion of the excrements of such animals as feed on saline plants.

The details of the process which is used have not been very long known. One of the first writers who gave a description of this operation is father Sicard. He informed us, in 1716, that distilling vessels were charged with the soot of the excrements of oxen, to which sea salt and camels urine were added.

Mr. Lemaire, consul at Cairo, in a letter written to the Academy of Sciences in 1720, affirms that neither urine nor sea salt are added.

Mr. Hasselquist has communicated to the Academy of Stockholm a considerably extensive description of the process: by which we learn that the dung of all animals which feed on saline plants is indiscriminately used, and that the soot is distilled, to obtain sal ammoniac.

This dung is dried by applying it against the walls: and it is burned instead of wood, in such countries as do not possess that fuel. The sublimation is performed in large round bottles of one foot and a half diameter, terminating in a neck of two inches in height; and they are

filled to within four inches of the neck. The fire is kept up during three times twenty-four hours; the salt is sublimed to the upper part of these vessels, where it forms a mass of the same figure as the vessels themselves. Twenty pounds of soot afford six pounds of sal ammoniac, according to Rudenskiold.

I was always of opinion that sal ammoniac might be extracted by treating the dung of the numerous animals which feed on saline plants in the plains of La Camargue and La Crau, in the same manner; and after having procured, with the greatest difficulty, two pounds of the soot, I extracted from it four ounces of sal ammoniac. I must observe, to save much trouble to those who may wish to follow this branch of commerce, that the dung produced during the summer, the spring, or the autumn, does not afford this salt. I did not know to what circumstance to attribute the versatility of my results, until I found that these animals do not eat saline vegetables, excepting at the time when fresh plants cannot be had; and that they are reduced to the necessity of having recourse to saline plants only during the three winter months. This observation appears to me to be a proof, that marine salt is decomposed in the first passages; and that the soda is modified to the state of ammoniac.

Sal ammoniac is continually sublimed through the apertures of volcanic mountains. Mr. Ferber found it; and Mr. Sage admitted its existence among volcanic products. It is found in the grottos of Puzzolo, according to Messrs. Swab, Scheffer, &c.

It is found in the country of the Calmucs. Model analyzed it.

It is also produced in the human body, and exhales by perspiration in malignant fevers. Mr. Model has proved this fact in his own person: for at the time of a violent sweat which terminated a malignant fever, he washed his hands in a solution of potash, and observed that a prodigious quantity of alkaline gas was disengaged.*

* Leblanc de Franciade was the author of a process, for making sal ammoniac in France. He covered the brick floor of an oven heated to redness, with common salt, and poured sulphuric acid upon it. The muriatic acid gas which arose was conducted by a brick gutter, into a large leaden chamber, where it met with a stream

Sal ammoniac crystallizes by evaporation in quadrangular pyramids. It is often obtained in rhombic crystals by sublimation. The concave face of the loaves of sal ammoniac in commerce is sometimes covered with these crystals.

This salt has a penetrating, acrid, urinous taste. It possesses a degree of ductility which renders it flexible, and causes it to yield to a blow of the hammer. It does not change in the air; which circumstance renders it probable that our sal ammoniac is different from that mentioned by Pliny and Agricola, as that attracted humidity. Three parts and a half of water dissolve one part of sal ammoniac, at sixty degrees of Fahrenheit's thermometer: a considerable degree of cold is produced by its solution.

One hundred parts of sal ammoniac contain fifty-two parts acid, forty ammoniac, and eight water.

This salt is not at all decomposed by clay; nor by magnesia except with difficulty, and in part only; but it is completely decomposed by lime and fixed alkalis. The sulphuric and nitric acids disengage its acid.

This salt is used in dyeing, to bring out certain colours. It is mixed with aqua fortis, to increase its solvent power.

It is used in soldering, in which operation it possesses the double advantage of clearing the metallic surface, and preventing its oxidation.

CHAPTER V.

Concerning the Nitro-muriatic Acid.

THE acid which we call Nitro-muriatic, is a combination of the nitric and muriatic acids.

Our predecessors distinguished it by the name of Aqua Regia, on account of its property of dissolving gold.

of ammoniacal gas, conducted thither from animal matters burning at the same time, in three large iron cylinders, placed in a furnace beside the former. These gases condensed by mixture and formed sal ammoniac.—*Am. Ed.*

There are several known processes for making this mixed acid.

If two ounces of common salt be distilled with four of nitric acid, the acid which comes over into the receiver will be good nitro-muriatic acid.

This is the process of Mr. Baumé.

The nitrate of potash may be decomposed by distilling two parts of muriatic acid from one of this salt: good aqua regia is the product of this operation; and the residue is a muriate of potash, according to Mr. Cornette.

Boerhaave affirms that he obtained a good aqua regia, by distilling a mixture of two parts of nitre, three of sulphate of iron or martial vitriol, and five of common salt.

The simple distillation of nitre of the first boiling affords aqua regia; which is employed by the dyers in the solution of tin, for the composition of the scarlet dye. This aqua fortis is a true aqua regia: and it is by virtue of the mixture of acids that it dissolves tin; for if it consisted of the nitric acid in a state of too great purity, it would corrode and oxide the metal without dissolving it. The dyers then say that the aqua fortis precipitates the tin; and they correct the acid by dissolving sal ammoniac or common salt in it.

Four ounces of sal ammoniac in powder, dissolved gradually, and in the cold, in one pound of nitric, form an excellent aqua regia. An oxygenated muriatic acid gas is disengaged for a long time; which it is imprudent to attempt to coerce, and which ought to be suffered to escape by convenient apertures.

Aqua regia is likewise formed by mixing together two parts of pure nitric acid and one of muriatic acid.

The very evident smell of oxygenated muriatic acid, which is disengaged in every process which can be adopted to form the acid at present in question; and the property which it possesses, equally with the oxygenated muriatic acid, of dissolving gold, have led certain chemists to infer that, in the mixture of these two acids, the muriatic acid seized the oxigene of the nitric, and assumed the character of oxygenated muriatic acid: so that the nitric acid was considered as answering no other purpose than that of oxygenating the muriatic. But this system is inconsistent; and though the virtues of the muriatic acid

are modified by this mixture, and it is oxidized by the decomposition of a portion of the nitric acid, nevertheless the two acids still exist in the aqua regia: and I am convinced that the best made aqua regia, saturated with potash, will afford the ordinary muriate, the oxygenated muriate, and the nitrate of potash. It appears to me that the powerful action of aqua regia, depends simply on the union of the two acids; one of which is exceedingly well calculated to oxidize the metals, and the other dissolves the oxides or calces with the greatest avidity.

CHAPTER VI.

Concerning the Acid of Borax.

THE acid of borax, more generally known by the name of Homberg's Sedative Salt, is almost always afforded by the decomposition of the borate of soda, or borax. But it has been found perfectly-formed in certain places; and we have reason to hope that we shall speedily acquire more accurate information respecting its nature.

Mr. Hoefer, director of the Pharmacies of Tuscany, was the first who detected this acid salt in the waters of the lake Cherchiajo, near Monte-Rotondo, in the inferior province of Sienna: these waters are very hot, and they afforded him three ounces of the pure acid in one hundred and twenty pounds of the water. This same chemist having evaporated twelve thousand two hundred and eighty grains of the water of the lake of Castelnuovo, obtained one hundred and twenty grains. He presumes, moreover, that it might be found in the water of several other lakes, such as those of Lasso, Monte-cerbeloni, &c.

Mr. Sage has deposited in the hands of the Royal Academy of Sciences some acid of borax, brought from the mines of Tuscany by Mr. Besson, who collected it himself.

Mr. Westrumb found sedative salt in the stone called Cubic Quartz of Luneburg. He obtained it by decomposing this stone by the acids of sulphur, nitre, &c. The result of his analysis is the following:

Sedative salt	-	-	$\frac{6}{10}$
Calcareous earth	-	-	$\frac{1}{10}$
Magnesia	-	-	$\frac{1}{10}$
Clay and silex	-	-	$\frac{2}{100}$
Iron	-	-	$\frac{1}{200}$ to $\frac{2}{200}$

This stone, according to the observations of Lassius, has the form of small cubical crystals, sometimes transparent, in other specimens milky, and affords sparks with the steel.

The acid of borax is generally found combined with soda. It is from this combination that it is disengaged, and obtained either by sublimation or crystallization.

When it is proposed to obtain it by sublimation, three pounds of calcined sulphate of iron, and two ounces of borate of soda are dissolved in three pounds of water. The solution is then filtered, and evaporated to a pellicle; after which the sublimation is performed in a cucurbit of glass with its head. The acid of borax attaches itself to the internal surface of the head, from which it may be swept by a feather.

Homburg obtained it by decomposing of borax with the sulphuric acid. This process succeeded with me wonderfully well. For this purpose I make use of a glass cucurbit with its head, which I place on a sand bath. I then pour upon the borax half its weight of sulphuric acid, and proceed to sublimation. The sublimed acid is of the most beautiful whiteness.

Stahl, and Lemery the younger, obtained the same acid by making use of the nitric and muriatic acids.

To extract the acid of borax by crystallization, the borax is dissolved in hot water, and an excess of sulphuric acid is poured in. A salt is deposited during the cooling on the side of the vessel, in the form of thin round plates, applied one upon the other. This salt when dry, is very white, very light, and of a silvery appearance. It is the acid of borax.

We are indebted to Geoffroy for this process. Baron has added two facts: the first, that the vegetable acids are equally capable of decomposing borax; and the second, that borax may be regenerated by combining the acid of borax with soda.

This acid may be purified by solution, filtration, and evaporation: but it must be observed, that a considerable part is volatilized with the water which flies off in the evaporation.

The acid of borax has a saline cool taste. It colours the tincture of turnsol, sirup of violets, &c. red.

One pound of boiling water dissolved no more than one hundred and eighty-three grains, according to Mr. De Morveau.

Alcohol dissolves it more easily; and the flame which this solution affords is of a beautiful green. This acid, when exposed to the fire, is reduced to a vitriform and transparent substance, instead of rising; which proves, as Rouelle has observed, that it is only sublimed by favour of the water, with which it forms a very volatile compound.

As most of the known acids decompose this acid, and exhibit it in the same form, it has been thought a justifiable conclusion that it exists ready formed in the borax. Mr. Baumé has even affirmed that he composed this acid by leaving a mixture of grey clay, grease, and cow's dung, exposed to the air in a cellar. But Mr. Wiegleb, after an unsuccessful labour of three years and a half, thinks himself authorized to give a formal negative to the French chemist.

Mr. Cadet has endeavoured to prove—1. That the acid of borax always retains a portion of the acid employed in the operation. 2. That this same acid has still the mineral alkali for its basis. Mr. De Morveau has, with his usual sagacity, discussed all the proofs brought forward by Mr. Cadet; he has shewn that none of them are conclusive, and that the acid of borax is entitled to retain its place among the chemical elements.*

* By digesting oxigenated muriatic acid on the acid of borax for a long time, Crell succeeded in decomposing it, and obtained from it a substance resembling charcoal in all its properties; and a volatile

ARTICLE I.

Borate of Potash.

The acid of borax combined with potash forms this salt. It may be obtained either by the direct combination of these two separate principles, or by decomposing borax by the addition of potash.

This salt, which is yet little known, afforded Mr. Baumé small crystals.

The acids disengage it by seizing its alkaline base.

ARTICLE II.

Borate of Soda.

This combination forms Borax, properly so called.

It is brought to us from the Indies; and its origin is still unknown.*

The article Borax may be consulted in Bomare's Dictionary of Natural History.

It does not appear that borax was known to the ancients. The chrysocola, of which Dioscorides speaks, was nothing but an artificial solder composed, by the goldsmiths themselves, with the urine of children and rust of copper, which were beaten together in a mortar of the same metal.

The word Borax is found for the first time in the works of Geber. Every thing which has been written since that time concerning borax, is applicable to the substance which is at present known to us by that name.

acid resembling the muriatic, in the greater number of its properties, but differing from it, in not precipitating lead from its solution. — *Am. Ed.*

* The origin of borax is very well ascertained in two papers, in the seventy-seventh volume of the Philosophical Transactions, numbers xxviii and xxix. It is dug up in a crystallized state from the bottom of certain salt lakes in a mountainous, barren, volcanic district, about twenty-five days journey to the eastward of Lassa, the capital of the kingdom of Thibet. T.

Borax is found in commerce in three different states.—

The first is brute borax, tincal, or chrysocolla. It comes to us from Persia, and is enveloped and soiled by a greasy covering. The pieces of brute borax have almost all of them the form of a six-sided prism, slightly flattened, and terminated by a dihedral pyramid. The fracture of these crystals is brilliant, with a greenish cast. This kind of borax is very impure. It is pretended that borax is extracted from the Lake of Necbal, in the kingdom of Grand Thibet. This lake is filled with water during the winter, which exhales in the summer; and when the waters are low workmen enter, who detach the crystals from the muddy bottom, and put them into baskets.

The West-Indies contain borax. It is to Mr. Antony Carera, a physician established at Potosi, that we are indebted for this discovery. The mines of Riquintipa, and those in the neighbourhood of Escapa, afford this salt in abundance. The natives use it in the fusion of copper ores.

The second kind of borax known in commerce comes from China. It is purer than the preceding, and has the form of small plates crystallized upon one of their surfaces, on which the rudiments of prisms may be perceived. This borax is mixed with a white powder, which appears to be of an argillaceous nature.

These several kinds of borax have been purified at Venice for a long time, and afterwards in Holland; but Messrs. Laguiller refine it at present in Paris: and this purified borax forms the third kind which is met with in commerce.

In order to purify borax, nothing more is necessary than to clear it of the unctuous substance which soils it, and impedes its solution.

Crude borax added to a solution of mineral alkali, is more completely dissolved, and may be obtained of considerable beauty by a first crystallization; but it retains the alkali made use of; and borax, purified in this manner, possesses a greater portion of alkali than in its crude state.

The oily part of borax may be destroyed by calcination. By this treatment it becomes more soluble, and may in fact be purified in this way. But the method is attended with a considerable loss, and is not so advantageous as might be imagined.

The most simple method of purifying borax, consists in boiling it strongly, and for a long time. This solution being filtrated, affords by evaporation crystals rather foul, which may be purified by a second operation similar to the foregoing. I have tried all these processes in the large way; and the latter appeared to me to be the most simple.*

Purified borax is white, transparent, and has a somewhat greasy appearance in its fracture.

It crystallizes in hexahedral prisms, terminated by trihedral and sometimes hexahedral pyramids.

It has a styptic taste.

It converts blue vegetable colours to a green.

When borax is exposed to the fire, it swells up, the water of crystallization is dissipated in the form of vapour; and the salt then becomes converted into a porous, light, white, and opaque mass, commonly called Calcined Borax. If the fire be more strongly urged, it assumes a pasty appearance, and is at length fused into a transparent glass of a greenish yellow colour, soluble in water; and which loses its transparency by exposure to the air, in consequence of a white efflorescence that forms upon its surface.

This salt requires eighteen times its weight of water, at the temperature of sixty degrees of Fahrenheit's thermometer, to dissolve it. Boiling-water dissolves one-sixth of its weight.†

* Nalmont Bomare informs us, that the Dutch extract eighty parts of pure borax, from one hundred of tincal. The operations are conducted in leaden vessels, and consist chiefly in repeated solutions, filtrations, and crystallizations. He suspects that they employ lime-water, and Fourcroy has shewn, that this might be useful in decomposing the soap in which crude borax is enveloped.—*Am. Ed.*

† When two pieces of borax are struck together in the dark, a flash of light is emitted.—*Am. Ed.*

Barytes and magnesia decompose borax. Lime-water precipitates the solution of this salt; and if quick-lime be boiled with borax, a salt of sparing solubility is formed, which is the borate of lime.

Borax is used as an excellent flux in docimastic operations. It enters into the composition of reducing fluxes, and is of the greatest use in analyses by the blow-pipe. It may be applied with advantage in glass manufactories; for when the fusion turns out bad, a small quantity of borax re-establishes it. It is more especially used in soldering. It assists the fusion of the solder, causes it to flow, and keeps the surface of the metals in a soft or clean state, which facilitates the operation. It is scarcely of any use in medicine. Sedative salt alone is used by some physicians; and its name sufficiently indicates its application.

Borax has the inconvenience of swelling up, and requires the greatest attention on the part of the artist who uses it in delicate works, more especially when designs are formed with gold of different colours. It has been long a desideratum to substitute some composition in the room of borax, which might possess its advantages without its defects.

Mr. Georgi has published the following process:—
“Natron, mixed with marine salt and Glauber’s salt, is to be dissolved in lime-water; and the crystals which separate by the cooling of the fluid may be set apart. The lixivium of natron is then to be evaporated; and this salt afterwards dissolved in milk. The evaporation affords scarcely one eighth of the natron employed, and the residue may be applied to the same uses as borax.”

Messrs. Struve and Exchaquet have proved that the phosphate of potash, fused with a certain quantity of sulphate of lime, forms an excellent glass for soldering metals.—See the *Journal de Physique*, t. xxix, p. 78, 79.

ARTICLE III.

Borate of Ammoniac.

This salt is still little known. We are indebted to Mr. De Fourcroy for the following indications :—He dissolved the acid of borax in ammoniac, and obtained by evaporation a bed or plate of crystals connected together, whose surface exhibited polyhedral pyramids. This salt has a penetrating and urinous taste ; it renders blue vegetable flowers green ; gradually loses its crystalline form, and becomes of a brown colour, by the contact of air. It appears to be of considerable solubility in water. Lime disengages the volatile alkali.

PART THE SECOND.

Concerning Lithology; or, an Account of Stony Substances.

INTRODUCTION.

THE object of Lithology consists in the study of stones and earths.

It is generally agreed to call those substances by the name of Earth or Stone, which are dry, brittle, inodorous, insipid, scarcely or not at all soluble in water, and of a specific gravity not exceeding 4,5.

There is no one who has seriously attended to the study of lithology, without being at the same time aware of the necessity of establishing divisions to facilitate the knowledge of stones, and to remove the numberless difficulties which would otherwise oppose the acquisition of that knowledge.

It is an obvious difference between living creatures and the subjects of the mineral kingdom, that these last are continually modified by external causes, such as air, water, fire, &c. while the former, being animated and governed by an internal force, possess characters of a more definite and unchangeable nature. The forms of these depend upon their organization; and, in general, the proceedings of nature respecting them are more constant, and better ascertained.

The earthy element appears to be passive of itself; it is obedient only to the laws of inanimate bodies; and we may refer all the phenomena of formation or decomposi-

tion, which a stone is susceptible of, to the mere law of affinities. This, no doubt, is the cause of that variety of forms, and that mixture of principles, which scarcely permit the naturalist to establish his system upon fixed bases, or to found it upon constant and invariable characters.

If we take a view of the proceedings of all the naturalists who have hitherto written, we may easily reduce them to three classes.

1. The first class, carried by the imagination alone to that epocha when this globe issued from the hands of the Creator, have followed the actions of the various destructive agents which alter or overturn its surface. In this way they have shewn us the various rocks successively deposited or placed upon the primitive globe; and, by surveying the great phenomena which have happened upon our planet, they have acquired ideas more or less accurate respecting the vast works of decomposition and formation.

2. Others have busied themselves in inquiring, by analysis, what are the earths or primitive matters out of which all the stones we are acquainted with are composed. This class of philosophers have supplied us with the most valuable acquisitions respecting the nature, the uses, and the decompositions of these substances: but the results of analysis, though necessary in acquiring accurate notions of each stone, are not of themselves sufficient to form the basis of a method of classing; because these characters are too difficult to be acquired, and at most can be used only as supplementary in the establishment of such other methods as may be employed.

3. Almost all the systems of classification hitherto adopted, are founded upon the external characters of earthy substances.

Some naturalists have sought, in the variety of forms exhibited by the productions of the mineral kingdom, such principles of division as to them appeared sufficient. But not to mention that the same form frequently obtains in very different stones, this character is rarely found, and we are ignorant of the crystallization of most of the known earths: the crystallization cannot therefore be considered but as an accessory or secondary circumstance.

Other naturalists have established their divisions upon certain properties easy to be ascertained, such as that of effervescing with acids, giving fire with the steel, &c. But these characters do not appear to be sufficiently strict, nor sufficiently exclusive; for nothing is more common than to find a mixture of the fragments of primitive rocks with those of calcareous stones. Our province exhibits examples of this every step we take; and these mixtures, hardened by time, possess both the fore-mentioned characters. There are also stones which, without changing their nature, give fire with the steel, or effervesce with acids, accordingly as they are more or less divided. Such is the lapis lazuli, which effervesces when pulverized, but strikes fire when in the mass; the slate likewise effervesces when in powder, but not in the mass. The classification, therefore, which is founded on these characters, is not rigorous, and may at the most be made use of in conjunction with others.

M. D'Aubenton is the naturalist who appears to me to have distributed mineral substances with the greatest order of any who has hitherto undertaken that task; every thing which he says on this subject, shews the experienced eye of the observer; and he has drawn from the external characters of bodies all the characters possible to be had from that source. But he could not avoid the defects which necessarily accompany the principles on which he has founded his system.

Deeply impressed with a sense of the insufficiency of these methods, as well as of the slight opportunities I have possessed of improving them, my endeavours have been exerted in collecting together all the characters which are capable of affording any useful indications. In this pursuit, I have joined the characters of the naturalist to those of the chemist; and though the method which I have adopted be very far from that degree of perfection which might be desired, I nevertheless present it to the public with confidence. It differs but little from that followed by Messrs. Bergmann and Kirwan; a circumstance which at least affords a prejudice in its favour. The peculiar advantages which, in my opinion, it appears to possess, are—1. The lithologic productions are distributed equally, and into three classes. 2. All the analogous productions are brought

together, and arranged as it were in a natural order. In a word, this system has fixed my own ideas in the most precise manner; and this has more particularly induced me to propose it to the public.*

The various earths beneath our feet are, in general, combinations; and chemists, by decomposing these substances, have succeeded in obtaining, in the last analysis, principles which may be considered as earthy elements, until subsequent acquisitions shall either confirm or destroy our ideas on this subject.

The earthy elements most extensively distributed are ten in number; namely, Lime, Magnesia, Barytes, Strontites, Alumine, Silex, Ytria, Glucina, Zirconia, and Agustina.

Nature appears to have formed all the mixtures and combinations which constitute stones, out of the primitive earths here spoken of.

If we direct our attention to the nature of these mixtures and combinations, we shall distinguish three habi-

* I consider what is here published respecting Lithology as a simple and short sketch of the principles which I explain in my Lectures. It would be judging me with too much severity, if the reader were to suppose that my present design is to exhibit a complete performance.

A more intimate acquaintance with this subject may be obtained by the perusal of the following works:

1. *Essai d'un Art de Fusion, à l'Aide de l'Air Vital*, par Erhmann. *Mémoires de M. Lavoisier sur le même sujet*.—*Mémoires de M. D'Arcet, sur l'Action d'un Feu égal, violent, et continu, sur un grand nombre de Terres, Pierres, &c.*

2. The works of Margraff and Pott, more especially the *Lithogognesia* of the latter.

3. *Les Pesanteurs Spécifiques des Corps*, par M. Brisson.

4. *Elements of Mineralogy*, by Mr. Kirwan.

5. *Le Manuel du Minéralogiste* de Bergmann, enrichi de Notes par M. L'Abbé Mongez.

6. *La Minéralogie* de M. Sage.

7. *Les Ouvrages sur la Crystallographie* de M. Romé de Lisle, de M. l'abbé Haüy, &c.

8. *Le Tableau Méthodique des Minereaux*, par M. D'Aubenton.

9. *La Minéralogie* de M. le Comte de Buffon; in which that celebrated writer has collected a great number of valuable facts, whose merit is independent of all theory.

10. *The Mineralogical Works* of Messrs, Jars, Dietrich, de Born, Ferber, Trebra, Pallas, Gmelin, Linné, Dolomieu de Saussure de la Peyrouse, &c.

11. *The excellent Analyses of Stones*, published from time to time by Pott, Margraff, Bayen, Bergmann, Gerard, Scheele, Achard, Mongez, &c.

tudes or modes, which establish three grand divisions. We shall immediately perceive that these earths are, in some instances, combined with acids, which form saline stones; that in other instances they are mixed with each other, and form stones properly so called; and that in other instances, again, these stones, so formed by the mixture of primitive earths, are united together, or fixed in a gluten or cement, which forms rocks, pebbles, or compound stones.

We shall therefore distinguish three classes in Lithology: the first will comprehend saline stones; the second stones, properly so called, or earthy mixtures; and the third rocks, or stony admixtures.

We consider it as indispensably necessary to explain the nature of the primitive earths, before we can proceed to treat of their combinations.

I. Lime.

This earth has been found totally disengaged from all combination, near Bath.—See Falconer on the Bath Waters, vol. i. p. 156 and 157. But as this is perhaps the only observation of the kind which we possess, it is indispensably necessary to shew the process by which lime may be obtained in a state of the greatest purity.

For this purpose chalk is to be washed in boiling distilled water, then dissolved in distilled acetic acid, and precipitated by the carbonate of ammoniac, or mild volatile alkali. The precipitate, being washed and calcined, is pure lime.

This earth possesses the following characters:

1. It is soluble in six hundred and eighty times its weight of water, at the temperature of sixty degrees of Fahrenheit. Kirwan.
2. It has a penetrating, acrid, and burning taste.
3. Its specific gravity is about 2,3 according to Kirwan, and 2,720 according to Bergmann.
4. It seizes water with great avidity; at the same time that it falls into powder, increases in bulk, and emits heat.

5. Acids dissolve it without effervescence, but with the production of heat.

6. The borate of soda, or borax, the oxides of lead, and the phosphates of urine, dissolve it by the blow-pipe without effervescence.

It appears to be infusible alone, as it has resisted the heat of flame urged by a stream of vital air.—See the Memoir of Mr. Lavoisier.

When it is mixed with acids, it forms a fusible combination; and it hastens the fusion of aluminous, siliceous, and magnesian earths, according to the experiments of Messrs. Darcet and Bergmann.

II. Magnesia, or Magnesian Earth.

This earth has been no where found disengaged from all foreign substances; but in order to obtain it in the utmost possible state of purity, the crystals of the sulphate of magnesia, or Epsom salt, are to be dissolved in distilled water, and decomposed by the carbonate of alkali. The precipitate must then be calcined, to disengage the carbonic acid.

1. Pure magnesia is very white, very friable, and, as it were, spongy.

2. Its specific gravity is about 2,33, according to Kirwan.

3. It is not perceptibly soluble in water when pure; but when it is combined with the carbonic acid, it is soluble; and cold water has a stronger action on it than hot, according to the experiments of Mr. Butini.

4. It has no perceptible action on the tongue.

5. It slightly converts the tincture of turnsol to a green.

6. Mr. Darcet has observed, that a strong heat agglutinates it more or less; but Messrs. De Morveau, Butini and Kirwan, found that it was not fusible; and the experiments of Mr. Lavoisier have proved that it is as infusible as barytes and lime.

The borate of soda, and the phosphates of urine, dissolve it with effervescence.—See the abbé Mongez.

III. Barytes, or Ponderous Earth.

We are indebted to the celebrated chemists Gahn, Scheele, and Bergmann, for our knowledge of this earth.

It has not yet been found exempted from all combination ; but in order to obtain it in a suitable degree of purity, the following process may be used :

The sulphate of barytes, or ponderous spar, which is the most usual combination met with on the earth, is to be pulverized, and calcined in a crucible, with an eighth part of powder of charcoal : the crucible must be kept ignited during an hour ; after which the calcined matter is to be thrown into water : it communicates a yellow colour to this fluid, at the same time that a strong smell of hepatic gas is emitted ; the water is then to be filtered, and muriatic acid poured in : a considerable precipitate falls down, which must be separated from the fluid by filtration. The water which passes through the filtre holds the muriate of barytes, or marine salt of ponderous earth, in solution. The carbonate of potash, or mild vegetable alkali, in solution, being then added, the ponderous earth falls down, in combination with the carbonic acid ; and this last principle may be driven off by calcination.

1. Pure barytes is of a pulverulent form, and extremely white.

2. It is soluble in about nine hundred times its weight of distilled water, at the temperature of sixty degrees, according to Kirwan.

3. The Prussiate of potash, or Prussian alkali, precipitates it from its combination with the nitric and muriatic acids. This habitude distinguishes it from other earths.—See Kirwan.

4. It precipitates alkalis from their combinations with acids.

5. Barytes exposed, by Mr. Lavoisier, to flame fed with oxigenous gas, was fused in a few seconds : it extended itself upon the surface of the coal ; after which it began to burn and detonate until the whole was nearly dissipated. This kind of inflammation is a character com-

mon to metallic substances; but when the barytes is pure it is perfectly infusible.—See Lavoisier.

Ponderous earth urged by the blow-pipe makes little effervescence with soda, but is perceptibly diminished: it dissolves in the borate of soda with effervescence, and still more with the phosphates of urine.—See the abbé Mongez' *Manuel du Minéralogiste*.

6. Its specific gravity exceeds 4,000, according to Kirwan.*

* IV. *Strontites*.

This mineral is met with in the lead mine of Strontian in Argyleshire, where it is found mixed with a variety of substances. It is united to the carbonic acid, forming carbonate of strontites.

Its specific gravity varies from 3.4 to 3.726.

Its texture is generally fibrous, and sometimes it is found crystallized, in slender prismatic columns of various lengths.

The carbonic acid may be separated from the carbonate of strontites, and the strontian obtained in a pure state, by mixing the mineral with powder of charcoal, and exposing the mixture to a high degree of heat; or the mineral may be dissolved in the nitric acid, the solution evaporated until it crystallizes, and the crystals exposed in a crucible to a red heat till the nitric acid is driven off.

Pure strontites has a caustic taste, it changes blue vegetable colours green, and unites oil with water. It attracts carbonic acid, from the atmosphere. When water is poured on strontites, it slacks, becomes hot, and falls into powder. One hundred and sixty-two parts of water, at the temperature of 60°, dissolve nearly one part of strontites. It combines with sulphur and phosphorus. It is not a poison to animals.

It tinges the flame of combustible bodies of a red colour. This experiment is performed, by moistening the nitrate of muriate of strontites with alcohol, in a silver spoon, setting fire to the mixture, and holding it when burning over the flame of a candle, in order to cause a quick and rapid combustion.

Many of the European mineralogists inform us, that sulphate of strontites is found at Frankstown in Pennsylvania. Klaproth analyzed a specimen from this place. He found its specific gravity to be 3.830. Its colour is a pale sky blue. It occurs in flat layers or strata from $\frac{1}{4}$, $\frac{1}{2}$ to $\frac{5}{8}$ of an inch thick, included between two even sides; which last partly appear to be real seams or joints, and partly are mere separating surfaces, formed by small clefts of the rock, filled with clay. On these exterior sides, the fossil has a dull appearance, but internally it is possessed of the ordinary lustre. It is easily communicated, and consists throughout of coarse parallel brittle fibres, which form needle shaped fragments.

V. Alumine, or Pure Clay.

This earth is not more exempt from mixture and combination than the foregoing; and in order to obtain it in a state of purity, the sulphate of alumine is dissolved in water, and decomposed by effervescent alkalis.

1. Pure clay seizes water with avidity, and may then be kneaded. It adheres strongly to the tongue.

2. Its specific gravity does not exceed 2,000, according to Kirwan.

3. When exposed to heat, it dries, contracts, shrinks, and becomes full of clefts. A considerable degree of heat renders it so hard that it gives fire with the steel.

When it has been well baked, it is no longer capable of uniting with water; but requires to be dissolved in an acid, and precipitated, in order that it may resume this property.

The experiments of Mr. Lavoisier shew that pure alumine is capable of an imperfect fusion, approaching to the consistence of paste, by heat excited by a current of vital air. It is then transformed into a kind of very hard stone, which cuts glass like the precious stones, and which very difficultly yields to the file.

The mixture of chalk singularly assists the fusion of this earth: it is fusible in a crucible of chalk, according to Mr. Gerhard, but not in a crucible of clay.

The borate of soda, and the phosphates of lime, dissolve it.—See Kirwan and the abbé Mongez.

According to the experiments of Mr. Dorthes, the purest native clays, and even that which is precipitated from alum, contain a small quantity of iron in the state of oxide; and it is from this principle that the earthy smell which is

One hundred parts of this blue fibrous sulphated strontianite, contain*

Strontian earth	58
Sulphuric acid	42
And a slight trace of oxidized iron	

100

Strontites may be obtained pure, from this sulphate, by following the process described for procuring barytes, in a state of purity.—*Am. Ed.*

* Klaproth's Analytical Essays, p. 394.

emitted by moistened clays, arises; it is very difficult to deprive them of it.

VI. Silex, or Quartzose Earth, Vitriifiable Earth, &c.

This earth exists nearly in a state of purity in rock crystal. But when it is required to be had in a state of purity free from all suspicion, one part of fine rock crystal may be fused with four of pure alkali. The fused mass must then be dissolved in water, and precipitated by an excess of acid.

1. Pure silex possesses a singular degree of roughness and asperity to the touch. It is absolutely void of all disposition to adhere; and its particles, when agitated in water, fall down with extreme facility.

2. Its specific gravity is 2,65.

3. Bergmann had affirmed that water might dissolve it; and Mr. Kirwan has pretended that 10,000 parts of water might hold one of silex in solution, at the ordinary temperature of the atmosphere; and might even take up a greater quantity at a higher temperature.

The fluoric acid dissolves it; and lets it fall when it comes in contact with water, or when it is considerably cooled.

5. Alkalis dissolve it in the dry way, and form glass; but they attack it likewise in humid way, and are capable of dissolving one-sixth part of their weight when it is in a state of extreme division.

6. The burning mirror does not fuse it; but a current of vital air produced a commencement of fusion on its surface.—See Lavoisier.

Before the blow-pipe soda dissolves it with effervescence. The borate of soda dissolves it slowly, and without ebullition.*

* VII. *Yttria*.

This mineral is found in the quarry of Ytterby, in Sweden. It is the heaviest of the earths. Its specific gravity is 4.842. It has neither taste nor smell. It is infusible by heat, but vitrifies with borax. It is insoluble in water, and has no action on blue vegetable colours. It dissolves in carbonate of ammonia, but is insoluble in the pure alkalis. It combines with the acids, and may be precipitated from them

CLASS I.

Concerning the Combination of Earths with Acids.

This class, which comprehends the combination of primitive earths with acids, naturally exhibits five genera.

by ammoniac, the prussiate of potash, and tannin. Its other properties have not been examined.

VIII. *Glucina.*

We are indebted to the celebrated Vauquelin, for the knowledge of this earth, who discovered it in the year 1795, in the emerald and beryl. It is found combined with silix, lime, alumine and oxide of iron. The word glucina is derived from the Greek γλυκύς, which signifies sweet, as it gives this taste to the salts it forms.

In order to obtain glucina, the beryl or emerald must be reduced to an impalpable powder, and melted with three times its weight of potash, and the mass dissolved in marine acid diluted with water, and the solution evaporated to dryness. The residuum is then to be mixed with a great quantity of water, and the whole thrown upon a filtre. The silix which constitutes more than half the weight of the stone, remains behind: but the glucina and other earths, being combined with muriatic acid, remain in solution. Precipitate them by a solution of the potash of the shop. Wash the precipitate in distilled water, and dissolve it in sulphuric acid. Add to the solution sulphate of potash: evaporate it to the proper consistency, and set it aside to crystallize. Crystals of alum will be gradually formed. When as many of these as possible have been obtained, pour into the liquid carbonate of ammoniac in excess, then filtre, and boil the liquid for some time. A white powder will appear, which is glucina.

Glucina is of a white colour, and soft to the touch, without either taste or smell. It adheres strongly to the tongue. It has no effect on vegetable colours. It cannot be melted by means of heat. It does not contract its dimensions like alumine. It is soluble in liquid potash and soda, and insoluble in ammoniac, but soluble in carbonate of ammoniac: it combines with the acids, and forms with them salts of a saccharine taste. Its specific gravity is 2.967.

IX. *Zirconia.*

We are indebted to the celebrated Klaproth for the discovery of this earth. It is found in a precious stone, called Zircon or Jargon. This gem was first brought from the island of Ceylon, but has also been met with in France, Spain, and other parts of Europe. Its colour is various, as grey, greenish-white, yellowish, reddish brown or purple, and violet. Accum says it has little lustre, and is nearly opaque, whereas Thomson informs us, it has a good deal of lustre, and is mostly semi-transparent. Its specific gravity is from 4.416 to 4.7, according to Kirwan.

GENUS I.

Earthy Salts with Basis of Lime.

The combination of lime with various acids affords the several species of calcareous salts comprehended in this genus.

Zircon earth possesses a very white colour, is exceedingly heavy, and harsh to the touch like silex; it is insoluble in water, but forms with it a jelly; it is destitute of taste and odour. It melts with borax into a transparent colourless glass. It undergoes a kind of imperfect fusion, when heated violently in a charcoal crucible, acquiring a grey colour, and something of the appearance of porcelain. In this state it is very hard, its specific gravity is 4.3, and it is insoluble in acids. It is insoluble in water, but has a considerable affinity for that liquid. When dried slowly, after being precipitated from a solution, it retains about one-third of its weight of water, and assumes a yellow colour, and a certain degree of transparency, which gives it a great resemblance to gum arabic.

It will not combine with oxygen, simple combustibles, nor metals. It has a strong affinity for several metallic oxides, particularly for the oxide of iron, from which it cannot be easily separated.

It is insoluble, even by boiling, in liquid alkalis, neither can it be fused with them by means of heat, but it is soluble in alkaline carbonates. We know not its affinity for the different earths. A mixture of alumine and zirconia is capable of fusion. It is of no use in medicine or the arts.

Zirconia is obtained in the following manner: Reduce the jargon to powder, mix it with three times its weight of potash, and fuse it in a crucible. Wash the obtained mass in distilled water, till the whole of the potash be extracted; then dissolve the residuum as far as possible in diluted muriatic acid. Boil the solution to precipitate any silex it may contain, filtre it, and gradually add a solution of potash. The zirconia will precipitate in the form of a fine white powder, which must be repeatedly washed in distilled water, and dried.

X. *Agustina.*

This earth is found in the Beryl of Saxony, and is so called, because it has the property of forming salts, which are nearly destitute of taste.

The properties of Agustina, according to Tromsdorff, are,

First. It is white and insipid, and when pure resembles alumine.

Secondly. It combines with acids, and forms with them salts, which have little or no taste.

Thirdly. It does not combine either in the humid or dry way, with alkalis or their carbonates.

Fourthly. It retains carbonic acid but feebly; and,

Fifthly. It is insoluble in water.—*Am. Ed.*

SPECIES I.

Carbonate of Lime, or Calcareous Stone.

The combination of lime with the carbonic acid is very commonly met with, and comprehends all the stones which have hitherto been distinguished under the names of lime-stone, calcareous stone, &c.

The characters of the carbonates of lime are—1. They effervesce with certain acids. 2. They are converted into lime by calcination.

The formation of these stones appears to us to be, for the most part, owing to the wearing down of shells. The identity of the constituent principles of shells and calcareous stones, and the presence of these same shells, more or less altered, in the lime-stone mountains, authorize us to conclude that a great part at least of the calcareous mass of our globe owes its origin to this cause only.

Though our imagination appears to assent with difficulty in referring effects of so wonderfully extensive a nature to a cause apparently so weak, we are compelled to admit it when we take a slight view of the known history of shells.

In fact, we observe the numerous class of shell animals which possess this stony covering almost at the instant of their origin. We see it insensibly become thick and enlarged by the apposition of new coverings: and this shell at length comes to occupy a volume fifty or sixty times larger than that of the animal which produced it. Let us consider the prodigious number of animals which emit this stony transudation; let us attend to their speedy augmentation, their multiplication, and the short period of their life, the mean term of which is about ten years, according to the calculation of the celebrated Buffon; let us multiply the number of these animals by the mass of shell they leave behind them—and we shall then arrive at the mass which the shells of one single generation ought to form upon this globe. If we proceed further to consider how many generations are extinct, and how many species

are lost, we shall be no longer surprized to find that a considerable part of the surface of the globe is covered with their remains.

It may easily be conceived that these shells, when carried along by currents of water, must strike together, and wear their respective surfaces; and that their pulverulent remains, after being long carried about and suspended by the waters, must at last subside, and form heaps or banks of shells, more or less altered according to circumstances.

But whatever may be admitted as the origin of this stone, it is found to exist in two principal states; that is to say, either in the form of crystals, or of irregular masses.

I. Crystallized Calcareous Stones.

A concurrence of circumstances which very seldom meet together, is required, in order that crystallization may take place. This is, doubtless, the reason why spars and calcareous crystals compose the smallest part of this genus. These crystals are found in the cavities of calcareous mountains; in the clefts which penetrate into the internal part of stones of this class; and generally in all places where waters find access, after having worn down calcareous stone to a state of extreme attenuation, nearly correspondent to solution.

Calcareous stone, in its crystallized state, presents us with several varieties of form; but the rhomboidal figure appears to be the most constant and the most general. The environs of Alais abound with rhomboidal spars of the greatest beauty; they are transparent like those of Iceland, and double objects in the same manner.

It often happens that a group of rhomboidal crystals exhibits at its surface a number of pyramids more or less prominent, which consist of the angles of rhomboids of different degrees of length. It cannot but be admitted, with Mr. Romé de Lisle, that the pyramidal form is a slight modification of the rhomboid; for if a pyramid of spar be broken, it is reduced into elements of a rhomboidal figure.

The principal varieties of the pyramidal form are deduced more especially from the number of their sides; and when the pyramid is long and sharp, it is called dog-tooth spar, or hog-tooth spar.

Calcareous stones often affect the prismatic form; and this is likewise attended with some varieties.

The prism is frequently six-sided and truncated; sometimes it is terminated by a trihedral pyramid; and when the prism is very short, and its summit is almost entirely in contact with the ground, the crystal is known by the name of Lenticular Spar.

All the varieties of form which crystallized calcareous stones have hitherto presented, may be seen in the Crystallography of Mr. Romé de Lisle.

The specific gravity of calcareous spars is about 2.700 when pure, according to Kirwan.

They contain from thirty-four to thirty-six parts of carbonic acid, and from fifty-three to fifty-five of earth; the rest is water.—See Kirwan.

Spars often exhibit a smooth uniform surface, upon which the sulphuric acid takes but slight hold: they are sometimes contaminated with iron, which gives them various tinges.

II. Calcareous stones which are not crystallized.

Few calcareous stones affect any regular form: they lie almost always in strata, or immense blocks thrown or heaped together on the surface of the globe, in which we cannot reasonably pretend to discern any primitive design of crystallization. The notion itself which we have of the formation of these mountains, and the stratified disposition of their parts, does not allow us to discern any other effect than the natural consequence of the flowing of water, which must have occasioned a contraction, and disposed the rocks in strata or beds.

It seems to me that two very natural divisions may be established among calcareous stones which are not crystallized: for they are either susceptible of a perfect polish,

in which case they are called marbles and alabasters; or they are not susceptible of this polish, in which case they are called friable earths, tufa, &c.

A. Calcareous stones susceptible of a perfect polish.

Although it be proved from the experiments of chemists, and more especially from those of Mr. Bayen, that marbles contain a greater or less proportion of clay, we are under the necessity of placing them here; because the calcareous earth predominates to such a degree, that they cannot with propriety be placed elsewhere; and because they possess all the characters of lime-stone.

Marbles differ from other calcareous stones by the polish of which they are susceptible; and they are distinguished from each other by their colours.

White marble is usually the purest. We are acquainted with the marble of Carrara, and the ancient statuary marble of Paros.

Black marble is coloured either by a bitumen or by iron. Mr. Bayen found this metal in the proportion of five parts in the hundred. When it is veined by pyrites, it is called Portor.

There are an infinite number of varieties of coloured marble. The colouring part is in general owing to the alterations of the iron, which sometimes is obedient to the magnet, according to an observation of Mr. De Lisle. Blue and green marbles owe their colours to a mixture of schorle, according to Rinmann in his History of Iron.

The marble which presents the figure of shells appears to be formed simply out of a heap of shells connected by a calcareous cement; it is known by the name of Lumachello. That of Bleyberg in Carinthia forms one of the most beautiful species.

The marble which is called figured marble, exhibits either traces of vegetables, as that of Hesse; or ruins and rocks, like that of Florence. The dendrites appear to be formed merely by ferruginous infiltrations through the cracks of these stones.

Several naturalists have mentioned flexible marble. Father Jacquier described this in 1764, in the *Gazette Littéraire*; and the abbé De Sauvages has communicated to

the Academy of Montpellier a description of the plates of flexible marble which are in the Palais Bourgeois.

Alabasters are calcareous stones of the nature of marble; they appear to be formed like the stalactites, and are sometimes adorned with the most beautiful colours: these in general possess a certain transparency, with a stratiform texture variously coloured, and cause a double refraction of the light when they are sufficiently transparent. In the treatise of Mr. Brisson on the specific gravities of bodies, the reader will find the result of his valuable experiments on that of marbles, alabasters, and generally all the calcareous stones.

B. Calcareous stone not susceptible of a perfect polish.

Calcareous stones which are not susceptible of a perfect polish, are found either in masses, or in the pulverulent form; which circumstance will afford a foundation for our natural distinction.

1. Solid calcareous stone is in general the stone used for building; and this is found in several varieties, differing in fineness of grain, porosity, colour, consistence, or weight. These are gradations which establish the several qualities of stones; and are the cause why one hardens in the air, while another is decomposed. On these several accounts it is that the respective varieties are applied to various uses; and it is the business of the skilful artist who uses them to distinguish their qualities.

In the number of these stones used for building, there are some which imbibe and retain water, in consequence of which they are burst or crumbled by the frost; whereas others suffer the water which they originally contained to escape, and become harder by the contact of the air.

2. Calcareous stone is sometimes found in the pulverulent form. Chalk is of this kind; and when it is white and very finely divided, it is formed into those masses known in commerce by the name of Spanish White. For this purpose it is agitated in a vessel with water. The foreign substances, such as flints, pyrites, &c. are precipitated; the water is then decanted; and the chalk, which is held suspended, very soon subsides: this is dried, and divided into long square pieces, to form the Spanish White.

When a natural stream of water wears away this chalk, and afterwards deposits it, the result has been distinguished by the name of Gurrh; and when this possesses a certain consistence, arising from the mixture of argillaceous and magnesian earths, it is distinguished by the name of Agaric Mineral.

As calcareous earth is susceptible of extreme division, the water which wears it away, and is afterwards filtered through the clefts in rocks, deposits it gradually, and forms those incrustations known by the vulgar under the name of Petrifications, and by that of Stalactites among naturalists.

These calcareous depositions very frequently preserve the form of such substances as they have covered, and present figures of moss, roots, fruit, &c. which has given rise to an opinion that those substances were transformed into stone.

The increase of stalactites being accomplished by addition to their external surfaces, their texture exhibits concentric coats of different shades, accordingly as the water may have been charged with different colouring principles.

The cavities which are frequently found in calcareous mountains are often lined with stalactites; and these grottos form one of the most striking appearances which can present itself to the eyes of the naturalist.

The grandeur of these subterraneous places, the absence of light, the feeble glimmering of a torch, which only half enlightens the surrounding objects, render these regions gloomy, majestic, and imposing. The multiplicity of figures, the variety of forms, and their resemblance to other objects, never fail to cause a high degree of astonishment in the mind of the mineralogical student. Among the infinite number of these forms, there are some which are very agreeable, such as the flos ferri, cauliflowers, lace, or fringes. Other very singular figures are likewise found, such as the priapolithes, pisolithes, oolithes, &c.

Mr. Lougeon of Ganges has observed, in the grotto called Des Demoiselles, a number of forms so varied and strange, as to exhibit a very astonishing collection.

These transudations, or rather these stony depositions, have given rise to a belief in the vegetation of stones. The celebrated Tournefort was of opinion that he had observed nature in the very fact, in the famous grotto of Antiparos, where he saw inscriptions engraved in the stone, but afterwards converted into reliefs. Baglivi has written a treatise on the vegetation of stones, in which he cites many facts of this nature.

All the world is acquainted with the depositions of the spring in the vicinity of Clermont; but the most surprising of all petrifying waters is that of Guancavelica in Peru. Barba, D. Ulloa, and Frezier, have given us a description of it. Feuille informs us that this water rises very hot in the middle of a square bason, and becomes petrified at a small distance from the spring. The water is of a yellowish white, and the incrustations have been used to build the houses of Guancavelica. The workmen fill moulds with its water, and some days afterwards they find them incrustated with this stone. The statuaries expose their moulds in this spring, and have only to give the polish in order to render their statues transparent. All the statues used in religious ceremonies, by the catholics of Lima, are of this substance, and are very beautiful. —*Journal des Observ.* tom. i. 434.

In the year 1760, Mr. Vegni devised a method of making a similar use of the very white chalk which is contained in the waters of the baths of St. Philip in Tuscany. For this purpose the water is suffered to run for the space of near a mile, in order that it may deposite the sulphur, the selenite, and the tufa which it contains; and in this purified state it is used in the fabrication of bas reliefs. It is introduced at the roof of a building, into a closet constructed of planks fitted together. The water falls from twelve to fifteen feet in height, upon a wooden cross placed on a post; by which fall it is divided, and dashes laterally against sulphur moulds, which are placed on the sides of the cabinet. In this way it deposite the particles of the earth which it contained, and the mould becomes filled. Mr. Vigni placed the moulds upon pieces of wood which are moved circularly. This alabaster is as hard as marble; and the incrustation is more beautiful,

and harder, in proportion as the position of the mould is more vertical, and its distance greater.

The Analysis and Uses of Calcareous Stone.

In 1755, Dr. Black proved that calcareous stone possesses, as one of its component parts, an air different from atmospheric air. He asserted that calcareous stone when deprived of this air by calcination, forms lime; and that lime might again pass to the state of calcareous stone by resuming the principle it had been deprived of. In 1764, Macbride supported this doctrine by new facts. Jacquin added other experiments to these; and proved that lime and alkalis owe their causticity to the subtraction of this fixed air, at the same time that he pointed out several methods of depriving them of it.

The processes which are most commonly used for the decomposition of lime-stone, are fire and acids; the first is used in the making of lime; the second in laboratories, when it is intended to procure the carbonic acid.

In order to form lime, the calcareous stone is calcined in furnaces, whose construction is varied according to the nature of the combustibles made use of.

When pit-coal is used, an inverted cone is constructed of vitrifiable stone, which is filled by alternate strata of coal and lime-stone; and the lime is taken out, after the operation, by an aperture at the top. In proportion as the mass subsides, care is taken to supply the furnace at the top, in order that the flame and heat may not be lost.

Bergmann has observed that most specimens of calcareous stone which become black or brown by calcination, contain manganese, and that the lime which they produce is excellent.

According to Rinmann, the white calcareous stones which become black by calcination, contain about one tenth part of this substance.

Calcination deprives lime-stone of the acid and water which it contained. These two principles are evidently replaced by the matter of heat itself. The odour of fire which quick-lime emits; the light which it affords when slackened in a dark place; the colour which it communi-

icates to the lapis causticus; the property which it possesses of producing the oxide and the glasses of lead—all prove to us, as Mr. Darcet observes in the *Journal de Physique* for 1783, that in proportion as the calcareous stone is deprived of the aëriform principle, it combines with the igneous principle, which cannot be displaced but by the way of affinities. The beautiful experiments of Meyer, when divested of all theory, prove the same thing.

It is proved, from the experiments of Dr. Higgins, that the best lime is that which is made with the hardest and most compact stone broken into small pieces, and heated slowly, until the furnace is become of a white heat. This heat must be kept up until the stone is no longer capable of effervescing with acids. The lime becomes over-burned if the ignition be carried to a greater degree; and the produce is then a frit, which is no longer capable of being divided in water, or of resuming with avidity the principles it had lost.

When pieces of calcareous stone of different sizes are calcined, the lime will not all be of equal goodness; the small pieces consisting of over-burned lime, while the larger pieces are scarcely altered in their central parts.

The best lime is that which is the most quickly divided by immersion in water, and affords the greatest quantity of heat in this process, which causes it to fall into the finest powder. Good lime should likewise dissolve in the acetous acid without effervescence, and leave the least possible quantity of residue.

Lime continually endeavours to resume the acid and the water of which the stone was deprived by calcination: consequently, when it is left exposed to the air, it cracks, becomes heated, falls into powder with an increase of bulk, and resumes the property of effervescing. It is therefore of importance to use lime newly made, if the artist be desirous of possessing its whole force.

Lime is sparingly soluble in water, and this solution is called lime-water; the lime may be precipitated by means of carbonic acid, which regenerates calcareous stone in the form of a precipitate.

Lime-water is used to indicate the presence, and determine the proportion, of carbonic acid in any mineral water.

Physicians prescribe it as an absorbent and detergent.

When lime-water is left in contact with the air of the atmosphere, a pellicle is formed at its surface, known by the name of the cream of lime; this is the regenerated calcareous stone.

The superb bason of Lampi, one of the two principal reservoirs which furnish the Royal Canal of Languedoc with water, was found to leak at the junction of the stones. The skilful engineer who directs these works, Mr. Pin, caused lime to be slacked; which, passing through these small apertures, became supplied with carbonic acid, and formed a crust, or very white covering, over its whole surface: so that all the stones of this fine piece of masonry are connected together by this cement; and at present constitute one single undivided substance, impenetrable to water.

The regeneration of calcareous stone is very slowly effected by the processes hitherto described. But this may be expedited by presenting to the lime the principles with which it so strongly tends to combine: this is accordingly done in works in the large way.

Lime is usually slacked by pouring abundance of water upon it. A violent heat is thus excited; the lime falls down into powder, and a paste is afforded by strongly working the lime together in proportion as it becomes saturated.

The count Razoumowski has taken advantage of the heat which is disengaged when lime is slacked, to combine the lime with sulphur.

The degree of heat proper to effect this combination is 70 of Reaumur. At this point the sulphur, which is placed in contact with the lime, liquefies, becomes of a red colour, and forms a true sulphure or hepar of lime.

Mortar is made simply by working sand, or other bodies insoluble in water, together with slacked lime.

We are acquainted with two kinds of sand at Montpellier; pit sand, and river sand: the former is almost always altered by a mixture of vegetable and calcareous earth, which weakens its efficacy; the second is purer, and better suited for the purpose. Instead of sand, the fragments or dust of stone may be used: the angles which

these fragments present, and the roughness of their surface, contribute to give a consistence to the mortar.

The hardening of mortars appears to be owing merely to the progressive regeneration of lime-stone. They do not obtain the greatest degree of hardness of which they are susceptible, until they have resumed all the carbonic acid of which the stone was deprived : and this operation is very slow, unless the combustion be facilitated by well-known methods, which consist in mixing substances with the mortar which contain either the carbonic acid, or a principle analogous to it, such as vinegar.

It is this regeneration of lime-stone, which is effected by the lapse of time, that explains to us why the hardest stones afford the best lime ; and why old mortars are found to possess a degree of hardness which modern artists have no hopes of attaining.

The remains of ancient buildings have induced certain philosophers to conclude, that the ancients were in possession of very valuable processes for the making of mortar. Mr. De la Faye was of opinion, that those enormous masses, in which the perfection of the mechanical processes of the ancients only was admired, were made by coffer work ; and he imagined that he had discovered, in Vitruvius, Pliny, and Saint Augustin, that their process to extinguish lime differed from ours ; and that the great difference which appears to exist between the ancient and modern mortars depends more particularly upon this circumstance. These interesting researches have induced him to propose that the lime should be put into a basket, and suffered to slack in the air ; as he thinks by this means it would preserve a greater degree of force, and be less weakened than by the usual processes.

Loriot has attributed the superiority of the mortars of the ancients to the means which they used to dry them speedily ; and in consequence of these principles he mixes pounded bricks with flints, works the whole together with slacked lime, and dries the mass with one-fourth part of quick-lime. Care must be taken to use only lime which is finely pulverized and sifted ; for otherwise the mortar would crack, and be very imperfect.

Nature sometimes presents to us a suitable mixture of lime-stone and sand, to form an excellent mortar without

any mixture of extraneous substances. Mr. De Morveau found this lime-stone in Burgundy; Mr. De Puymaurin has described a species which he found in Berne; and I have observed in Cevennes a natural mixture of this kind, in which the proportion of materials was so well assorted, that nothing more was necessary than to calcine it, and extinguish it in water, to form an excellent mortar.*

SPECIES II.

Sulphate of Lime, Gypsum, Selenite, Plaster Stone.

The Plaster Stone loses its transparency by calcination; at the same time that it becomes pulverulent, and acquires the property of again seizing the water of which it had been deprived, and resuming its hardness; it does not give fire with the steel, nor effervesce with acids.

We are more particularly indebted to Margraff for our acquaintance with the constituent principles of plaster; and from subsequent experiments the following proportion of the same principles has been assigned. One hundred parts of gypsum contain thirty sulphuric acid, thirty-two pure earth, thirty-eight water; it loses nearly twenty per cent. by calcination.

We begin to be equally acquainted with the formation of this stone. The chevalier De Lamanon has asserted, that the numerous quarries of plaster which are found in

* Only one vein of lime-stone is known below the blue ridge in Virginia. Its first appearance is in the county of Prince William, two miles below the Pignut ridge of mountains, and is never more than one hundred yards wide. Lime-stone is found on the Mississippi and Ohio, and in all the mountainous country between the eastern and western waters, occupying the valleys between the mountains.*

Dr. Mitchell informs us that there is a mass of it eight hundred acres in extent, near Claverack, New-York, which is remarkable for its petrifications.

In travelling from Albany to the Ballstown springs, and from thence through the Genesee country to the falls of Niagara, rocks of lime-stone are every where met with, covered with the impressions of shells.

It is also found in immense quantities in Pennsylvania, Maryland, North-Carolina, and Massachusetts.—*Am. Ed.*

* Jefferson's Notes on Virginia, p. 43.

the vicinity of Paris, are the deposition of an ancient fluviatile lake, formed by the Seine, Loise, and Marne, which flowed off on the side of Meulan. The wrought iron, and the various remains of animals which are found at the bottom of the quarries of Mont Matre, shew that its formation is not very ancient; and the indefatigable naturalist here cited considers the selenite as originally dispersed in the water, precipitated in consequence of its sparing solubility, and heaped together in places determined by currents, waves, and other circumstances.

These facts highly interesting as they are in the natural history of plaster, are insufficient for the chemist who is desirous of knowing likewise in what manner, and under what circumstances, the combination of the sulphuric acid and lime is made. I shall proceed to communicate some observations which our province affords.

1. I have observed in a black and pyritaceous clay of Saint Sauveur, extracted out of the work called Perce-ment Dillon, many small needle-formed crystals of selenite, from four to eight lines in length. At the surface of the soil where the same clay is more decomposed, crystals of the same nature, but longer, thicker, and more numerous, are also found.

2. The marly and pyritous clay of Caunelle, near Mosson, abounds with beautiful crystals of rose-coloured plaster, in the form of cocks' combs, observed by Mr. Dorthes.

3. The plaster quarry of La Salle exhibits almost alternately strata of plaster and strata of black and pyritous clay, which effloresces in the air.

4. Near the bridge of Herepian, on the declivity of Caseastel, at Gabian, and in many other places, I have constantly found crystals of gypsum mixed and confounded with pyritaceous clays.

5. The sulphureous depositions of solfatara often contain crystals of selenite.

From these facts it appears to me that the formation of gypsum may easily be conceived. It is not formed excepting in places where pyrites and clay more or less calcareous are found together: that is to say, its formation

appears to be dependant on, and connected with, the presence of sulphur and lime.*

Whenever, therefore, the pyrites is decomposed, the sulphuric acid which thence arises seizes the lime, and effloresces in small crystals, which are carried off by the water, and sooner or later deposited. I have observed perceptible depositions of plaster on the banks of rivulets which wash pyritous clays. I have likewise seen depositions of the same nature in rivers whose waters have been strongly concentrated by the burning heat of our summer. And consequently, if we suppose selenite to be dispersed in more considerable masses of water, there will be no difficulty in conceiving the formation of those strata which the plaster quarries exhibit.

Messrs. De Cazozy and Macquart have observed the transition of the gypsum of Craevia to the state of calcedony. When the nucleus of calcedony is determined, it increases perceptibly in the course of time, even in cabinets; which proves that the quartzose juice, when once infiltrated into plaster, combines with the lime, and determines this transformation.

Mr. Dorthes has proved that the quartz, in cocks' combs at Passy, owed its origin to plaster; that this last substance having been carried away by solution, the quartzose juice has taken its place. Natural history exhibits several of these metamorphoses.

Gypsum is found in the earth in four different states.

1. In the pulverulent and friable form, which constitutes gypseous earth, fossil flour, &c.
2. In solid masses, which constitute plaster stone.
3. In stalactites, or secondary depositions. In this place we may arrange the striated silky gypsums, the cauliflowers, the gypseous alabasters, and that prodigious variety of forms which the stalactites assume, whatever may be its component parts.

* It is formed in this manner, at the falls of Niagara. Sulphur of a white colour is found adhering to the sides of the great rocks, at this place, and there is a spring, emitting sulphurated hydrogen gas, within a mile of the falls.

The rocks consist of a species of calcareous earth, called the swine stone, and when small pieces of them are rubbed together, they emit a strong hepatic smell.—*Am. Ed.*

4. In determinate crystals, which usually exhibit the following forms.

1. The compressed tetrahedral rhomboidal prism.

2. The hexahedral prism truncated at its summit.

3. The decahedral rhomboid. I apprehend that the lenticular gypsum may be referred to this last form, as it appears to me to be composed of several rhomboids united together side-ways. At all events I have, as the last result, obtained the rhomboidal form, by decomposing this variety.

The colour of gypsum is subject to a great number of varieties, which are the signs of various qualities relative to its uses. The white is the most beautiful, but sometimes it is grey; and in this case is less esteemed, and less valuable.

The several states of the oxides of iron, with which it abounds in greater or less quantities, constitute its rose-coloured, red, black, &c. varieties.

The specific gravity of gypsum varies according to its purity.—See Messrs. Brisson and Kirwan: the latter found it sometimes of the weight of 2.32, and sometimes 1.87.

It is soluble in about five hundred times its weight of water, at the temperature of 60 degrees of Fahrenheit.

When it is exposed to heat, its water of crystallization is dissipated, it becomes opaque, loses its consistence, and falls into powder. If it be moistened, it becomes hard again, but does not resume its transparency; a circumstance which appears to prove that its first state is a state of crystallization.

If it be kept in a fire of considerable intensity, in contact with powder of charcoal, the acid is decomposed, and the residue is lime.

Its principles may likewise be separated by finely pulverizing it, and boiling it with alkali.

It is fusible by the blow-pipe according to Bergmann; and in a porcelain furnace, according to Darcet.

The management of the fire in the calcination of gypsum is of great consequence. Too much heat decomposes it; and too little does not enable it to unite, and form a hard substance with water.

Calcined gypsum divides and disperses itself in water, with which it forms a paste that may be cast into every

figure imaginable. We are indebted to this property for beautiful ornaments in the inside of our houses; but it cannot be used for external decorations, because its solubility in water renders it gradually destructible by that liquid.*

SPECIES III.

Fluate of Lime, Vitreous Spar, Fusible or Phosphoric Spar, Fluor Spar.

This stone is a combination of a peculiar acid, called the fluor acid, with lime.

It decrepitates on heated coals, like muriate of soda, or common salt. When slightly heated, it shines with a beautiful blue colour, that remains even under water, or in acids. The residue of this appearance of combustion is white and opaque.

Its specific gravity is, in general, from 3.14 to 3.18, according to Kirwan.

This spar enters into fusion by a strong heat, and corrodes the crucible: it likewise fuses without effervescence with the mineral alkali, the borate of soda, and the phosphates of urine.

This stone possesses the most lively and various colours; and it is known under the names of false emerald, false amethyst, or false topaz, accordingly as its colour is green, violet, or yellow.

The blue fluor spars commonly owe their colour to iron, but sometimes to cobalt. Berlin Berchraft, tom. ii. p. 330.—Green fluors are coloured by iron, according to Rinmann. The most usual form of fluuate of lime is the cubic, with all the modifications which accompany this primitive form.

* There is but little gypsum in the United States. It is found of a very white colour, imbedded in rocks of swine stone, at the falls of Niagara, and has absurdly been called the spray of the falls.

It is said to have been discovered in the state of New-York, on the nine mile creek, or outlet of the Owasco lake, and at the falls of the Genesee river, and in Virginia, upon one of the head waters of the Staunton, about twenty-five miles from Fincastle.†—*Am. Ed.*

† Barton's Phys. and Med. Journal, vol. i.

When this stone is distilled with its own weight of sulphuric acid, the first product consists of elastic whitish vapours, which fill the receiver, and deposite a crust at the surface of the water, while the water itself becomes acidulous. The residue in the retort is sulphate of lime, according to Scheele. The crust which is formed on the water of the receiver is siliceous earth; and the water itself being saturated with the vapour, constitutes the fluoric acid.

The most astonishing property of this acid is doubtless that of seizing the siliceous earth, which is a constituent principle of the glass, and volatilizing it with itself.

In order to have the acid in a state of greater purity, and exempt from every mixture of silex, the operations are performed in retorts of lead; but Mr. De Puymaurin is convinced, as well as myself, that the acid even then is seldom pure, because the most beautiful fluor contains almost always a small quantity of silex, which the acid carries with it. The whitest, the most transparent, and the most regularly-crystallized fluor, distilled on the water bath in a leaden retort, afforded me an acid contaminated by a small quantity of silex.

Mr. Meyer having used every possible means to obtain this acid in a state of great purity, is convinced that when the acid does not find silex in the retort, it attacks the sides of the receiver, and becomes changed.

This acid may be preserved in bottles whose internal surfaces are coated with wax dissolved in oil.

The fluoric acid has some analogy with the muriatic; and some chemists have even confounded them together: but they differ essentially from each other.

The fluoric acid—1. When combined with potash, presents a gelatinous substance, which when dry retains one-fifth of the alkali employed, and forms a true neutral salt. 2. It acts nearly in the same manner with soda. 3. With ammoniac it affords a jelly, which when dry exhibits all the appearances of silex. 4. When mixed with lime water, it regenerates the fluat of lime. 5. It does not attack gold, nor dissolve silver; and combines in preference with oxides, such as those of lead, iron, copper, tin, cobalt, and even of silver.

One part of the fluuate of lime, fused with four parts of caustic fixed alkali, forms a salt insoluble in water. The same quantity of fluuate of lime, treated in the same manner with the carbonate of potash, or mild vegetable alkali, affords a soluble salt; and at the bottom of the water a calcareous earth is found, which proves that the fluoric acid is not separated but by double affinity.

This stone, which hitherto has not been employed but as a flux, or in the fabrication of ornaments, appears to me to deserve the most particular attention. Its texture seems to be lamellated like the diamond; and like that stone it is capable of double refraction, as the abbé Rochon has observed. Its phosphorescence has likewise some relation with the combustibility of the diamond, and it has lively and varied colours. All these circumstances establish an analogy between these two substances; and might lead us to suspect that the constituent principles of the diamond exist in this stone, mixed and combined with an acid and lime, &c.

The fluoric acid possesses the very singular property of attacking glass, and dissolving and carrying off its siliceous part. Margraff first observed this property; but Messrs. De Puymaurin and Klaproth have very happily applied it to the art of engraving on glass.

This acid is employed to corrode the glass, in the same manner as aqua fortis is used to engrave upon copper.

Some authors, particularly Mr. Monnet, have endeavoured to prove that this acid was nothing else but a modification of the acid used in the decomposition of the spar. They seem to found their opinion chiefly on the circumstance, that the acid obtained exceeds in weight the spar made use of; but they have neglected the increase of weight which must arise from the erosion, dissolution, and mixture of the glass of the distilling vessels. And indeed these experiments do not appear to me to invalidate in the least the eternal truths which have issued from the laboratory of the celebrated Scheele; otherwise such modifications in the acids employed, would in my opinion afford a phenomenon still more astonishing than the existence of this peculiar acid.*

* Fluoric acid has been found in the enamel of the human teeth and in ivory by Marechini and Guy Lussac. It is a remarkable fact,

SPECIES IV.

Nitrate of Lime, Calcareous Nitre.

This salt, as well as those which remain to be treated of in the present genus, exists only in waters. Their great solubility, and their spontaneous deliquescence, do not permit them to form durable masses, or to exist in the form of stones.

The nitrate of lime is principally formed near inhabited places; old plaster affords it in abundance by lixiviation. It is one of the salts which abound in the mother waters of the salt-petre makers; and it has been found in some mineral waters.

It is usually obtained in the form of small needles, applied sideways to each other.

When a solution of nitrate of lime is concentrated to a gelatinous consistence nearly equal to that of syrup, it forms, in process of time, crystals in hexahedral prisms. Two parts of cold water dissolve one of this salt; and boiling water dissolves more than its own weight.

Its taste is bitter and disagreeable.

It liquefies easily on the fire, and becomes solid by cooling: if it be strongly calcined, and carried into the dark, it is luminous, and constitutes Baldwin's phosphorus.

It loses its acid in a violent and continued heat. When distilled in close vessels, it affords the same products as nitre by the decomposition of its acid.

Projected upon ignited coals, it detonates in proportion as it becomes dry. See De Fourcroy.

Its acid may be disengaged by means of clay and of the sulphuric acid.

The alkalis and barytes precipitate its earth.

The sulphuric salts, and the carbonates of alkali, decompose it by double affinity.

that as in the teeth, the fluoric acid occurs in combination with the phosphoric acid, the phosphate of lime, brought from Estremadura contains likewise fluuate of lime.—*Am. Ed.*

SPECIES V.

Muriate of Lime, Calcareous Marine Salt.

This combination exists more especially in the waters of the sea; and contributes to give to these waters that bitter taste which has improperly been referred to bitumens that have no existence.

This salt is very deliquescent; one part and a half of water dissolves one of this salt; and hot water dissolves more than its own weight.

It may be made to crystallize by concentrating its solution to the 45th degree of Baumé, and exposing it afterwards in a cool place.

With these precautions it affords a salt in tetrahedral prisms terminated by four-sided pyramids.—See De Fourcroy.

It enters into fusion with a moderate heat; but is decomposed with great difficulty. It acquires by calcination the property of shining in the dark, and is called the phosphorus of Homberg.

It is decomposed by barytes and the alkalis. The concentrated sulphuric acid, poured upon a very strong solution of muriate of lime, disengages the acid in vapours, and forms a solid precipitate; an appearance which seems in an instant to transform two liquids into a solid, and produces a very striking effect. The theory of this phenomenon is easily deduced from the very great solubility of the muriate, and the almost absolute insolubility of the sulphate which takes its place.

SPECIES VI.

Phosphate of Lime, Calcareous Phosphoric Salt.

This phosphate of lime has been found in Spain, in the kingdom of Estremadura, by Mr. Bowle.

It is a whitish stone of considerable density, not hard enough to give fire with the steel. It is found in horizon-

tal strata, reposing upon quartz, and exhibiting vertical, flattened, and close fibres. When thrown on ignited coals, it does not decrepitate, but burns quietly, and affords a beautiful green light, which seems to penetrate through it, and does not disappear so quickly but that a sufficient time is admitted to contemplate its brilliancy with admiration. Before the blow-pipe it runs into a white enamel, without boiling up; whereas bones support the most violent heat without fusion. Its habitudes with the nitric and sulphuric acids are the same as those of calcined bones; its acid may be separated and brought into the state of an animal glass; it may be decomposed, and the phosphorus extracted.

Mr. Proust, from whom we borrow these interesting details, observes likewise that this stone is found to compose the mass of entire hills in the neighbourhood of the village of Logrosan, in the jurisdiction of Truxillo, a province of Estremadura. The houses and the walls of inclosures are built of it.

GENUS II.

Earthy Salts with Base of Barytes.

The most common state in which Barytes is found is in combination with the sulphuric acid.

SPECIES I.

Sulphate of Barytes, Ponderous Spar.

This stone is the most ponderous we are acquainted with. Its specific gravity is commonly from 4 to 4.6.

It decrepitates in the fire, melts before the blow-pipe without addition, and fluxes dissolve it with effervescence.—See the notes of the abbé Mongez.*

Mr. Darcet succeeded in fusing it in a porcelain furnace.

* Manuel du Mineralogiste.

It has been often confounded with gypsum and fluor spar; but the characters of these two substances are very different.

It almost always accompanies metallic ores, and it is even considered as an happy presage of finding them. Becher has affirmed that it was a certain indication *vel presentis vel futuri metalli*: and I think that there is reason to consider it as the vitrifiable stone of this celebrated naturalist. The proofs of my assertion may be seen in the preliminary ideas of my treatise on metallic substances (in this work). The analogy between this stone and metals has been established by the experiments of Bergmann and of Mr. Lavoisier.

This stone, when rather strongly heated, exhibits a blueish light in the dark. To form these kinds of phosphori, the spar is pulverized, the powder is kneaded up with mucilage of gum tragacanth, and the paste is formed into pieces as thin as the blade of a knife. These pieces are afterwards dried, and strongly calcined by placing them in the midst of the coals of a furnace; they are afterwards cleared by blowing on them with the bellows. In this state, if they be exposed to the light for a few minutes, and afterwards carried into a dark place, they shine like glowing coals. These pieces shine even under water; but they gradually become deprived of this property, which however may be restored again by a second heating.— See De Fourcroy.

Ponderous spar is easily divided into plates by the slightest blow; and the most usual form which it affects is that of an hexahedral prism, very flat, and terminated by a dihedral summit.

Ponderous spar has been found at the distance of one league from Clermont d'Auvergne, in the form of hexahedral prisms terminated by a tetrahedral or dihedral pyramid. I have seen crystals of two inches in diameter.

It frequently happens that the form of these crystals is not very determinate; but all the stones of the nature of these exhibit a confused assemblage of several plates applied one upon another, and capable of being separated by a very slight blow. Ponderous spar is insoluble in water; and upon this property is founded the virtue possessed by the muriate of barytes, to manifest the slightest

portions of sulphuric acid in any combination which contains it.

Barytes adheres more strongly to acids than the alkalis themselves do; and when the carbonates of alkalis precipitate it, the effect takes place in the way of double affinity.*

SPECIES II.

Carbonate of Barytes.

This combination has the specific gravity of 3.773.

One hundred parts contain twenty-eight water, seven acid, sixty-five pure earth.

The sulphuric, nitric, and other acids attack it with effervescence.

Although the carbonic acid possesses the strongest affinity with this earth, it is very seldom found in combination with it: and I am acquainted with its existence only on the authority of Mr. Kirwan, who affirms that Dr. Withering presented him with a specimen from Alston Moor, in Cumberland; which resembles alum, with the difference that its texture is striated, and its specific gravity is 4.331.†

Mr. Sage analyzed this stone, which was presented to him by Mr. Greville.—See the *Journal de Physique* for April 1788.

* Sulphate of barytes has been discovered of a white colour and laminated texture, in Sussex county, New-Jersey. It has also been found in the sugar loaf mountain, not far from the junction of the Monocasy, with the Potowmac, in Maryland, and in Bottertot county, Virginia. Lapis Hepaticus, the liver stone of the Germans and Swedes, or bituminous sulphate of barytes, is likewise found in the county of Albemarle, Virginia.—*Am. Ed.*

† It is plentifully found in England, in the lead mine of Anglezark, near Chorley in Lancashire. See the *Manchester Memoirs*, vol. iii. p. 598. T.

SPECIES III.

Nitrate of Barytes.

The nitric acid dissolves pure barytes, and forms a salt which crystallizes sometimes in large hexagonal crystals, and frequently in small irregular crystals.

This nitrate is decomposed by fire, and affords oxygen gas.

The pure alkalis do not disengage the barytes, but the alkaline carbonates precipitate it by double affinity.

The sulphuric and fluoric acids seize this earth from the nitric acid.

It has not yet been found native.

SPECIES IV.

Muriate of Barytes.

This salt is capable of assuming a form considerably resembling that of spar in tables or plates. It exhibits, with the earths, acids, and alkalis, phenomena nearly similar to those of the nitrate of barytes.

It forms one of the most interesting re-agents to ascertain the existence of the smallest particle of sulphuric salt in any water; because, by the sudden exchange of principles, the result is ponderous spar, which immediately falls down.

It has not yet been found in a native state.

GENUS III.

Earthy Salts with Basis of Magnesia.

These salts were not well known before the time in which the celebrated Black proved that they ought not to be confounded with calcareous salts. They may be

distinguished from these by the bitter taste which almost all of them possess.

They are in general very soluble in water. Lime-water precipitates them, as does likewise ammoniac, or the volatile alkali.

SPECIES I.

Sulphate of Magnesia, Epsom Salt.

This salt is frequently met with; it exists in several mineral waters, such as those of Epsom, of Sedlitz, &c. It was at first distinguished by the name of the springs which produced it; and it is still known by the name of the bitter cathartic salt, on account of its taste and virtues.

The sulphate of magnesia, in commerce, comes either from the salt springs of Lorraine, from which this salt is extracted with a mixture of sulphur; or otherwise from the salt works in the environs of Narbonne, where it is extracted from the mother waters which contain it abundantly.

The sulphate of magnesia, in commerce, has the form of small silky needles, very white. It does not effloresce in the air, which distinguishes it from the sulphate of soda.

The crystals of the pure sulphate of magnesia are quadrangular prisms, terminated by pyramids of an equal number of sides.

The sulphate of magnesia prepared in our salt works is sold at from thirty to forty livres the quintal; it contains in the pound three sixteenths of sulphate of soda, two sixteenths muriate of magnesia, one sixteenth muriate of soda, six sixteenths true sulphate of magnesia: the rest consists of salts with basis of lime.

The sulphate of magnesia, when exposed to the fire, liquefies, and loses half its weight. The remainder is dry, and requires a strong fire to fuse it.

Water dissolves its own weight of this salt, at the temperature of 60 degrees of Fahrenheit's thermometer.

One hundred parts of this salt contain twenty-four parts acid, nineteen earth, and fifty-seven water.

It exists in all the waters in the environs of Montpelier.

Sometimes it is found efflorescent upon schisti, from which it may be collected. I have found it upon a mountain in Rouergue, in a quantity sufficiently great to be collected to advantage: birds of passage devour it greedily. This salt is used in preference to others as a purgative.*

[SPECIES II.]

Nitrate of Magnesia.

The celebrated Bergmann, who has combined magnesia with the various acids, observes that the nitric acid forms with it a salt capable of affording, by proper evaporation, prismatic, quadrangular, truncated crystals. The same chemist adds, that this salt is deliquescent. Mr. Dijonval affirms, that he obtained crystals that were not deliquescent; and accident has afforded me a salt of this kind in mother water of nitre concentrated to the 45th degree of the aerometer. Its form was that of prisms with four sides, very much flattened, very thick, and very short.

This salt decomposes the muriates; alkalis precipitate its magnesia, as does likewise lime.

SPECIES III.

Muriate of Magnesia.

The muriate of magnesia exists in the mother water of our salt works; its taste is very bitter.

According to Bergmann, it forms a salt in small needles, so deliquescent that it cannot be obtained but by strongly concentrating the solution, and afterwards exposing it to intense cold.

* Immense quantities of this salt are found under the surface of the earth in Monroe county, Virginia.—*Am. Ed.*

Lime-water, barytes, and the alkalis precipitate the magnesia; it may likewise be separated by means of fire.

SPECIES IV.

Carbonate of Magnesia.

Though magnesia has the greatest affinity with the carbonic acid, I do not think that nature has ever exhibited this combination. It is obtained by precipitating the magnesia from Epsom salt, by means of the carbonates of alkali; and in this state it is called effervescent magnesia, or magnesia not calcined.

The carbonate of magnesia contains in the quintal thirty parts acid, forty-eight earth, and twenty-two water.— See Kirwan and Bergmann.

Magnesia sticks to the tongue; and assumes, in drying, a certain transparency, which it preserves until it has lost all its water, which is not easily driven off.

Fire carries off the water and the acid; and in this state the residue is called calcined magnesia.

The carbonate of magnesia is soluble in water in the proportion of several grains in an ounce of the fluid.

But we are indebted to Mr. Butini for a very singular observation—that cold dissolves more than hot water, and that the magnesia may be precipitated by heating the water which holds it in solution. Hence it arises that waters loaded with magnesia become white and turbid by ebullition.

The celebrated Bergmann had advanced that the carbonate of magnesia is crystallizable. Mr. Butini, by concentrating a saturated solution of this salt with a gentle heat, obtained groups of crystals, which, when examined by the microscope, appeared to be hexagonal truncated prisms. I have obtained similar snow-like flocks by precipitating magnesia by the addition of an alkali, drop by drop.

The carbonate of magnesia is used in medicine as a purgative. The calcined magnesia ought to be preferred as an absorbent.

GENUS IV.

Earthy Salts with Base of Alumine.

The substance which in the arts is known by the name of Clay, is a natural mixture of several earths.

Alumine, or pure clay, is capable of combining with the greatest part of the known acids; but the most common of these salts is alum.

SPECIES I.

Sulphate of Alumine, Alum.

Though alum be very commonly met with, yet the combination of principles which constitute it is not effected without considerable difficulty.

Pure clay upon which the sulphuric acid is digested, is dissolved with difficulty; and it is by no means easy to bring this combination to regular crystals. The usual product is a salt, which appears to be formed by scales applied one upon the other.

The most ordinary process to dissolve alumine by means of an acid, consists in calcining the clay, impregnating it with the acid, and facilitating its action by an heat of 50 or 60 degrees of Reaumur. But a simpler method, which I have used in my manufactory of alum, consists in presenting the acid in vapours, and under the dry form to the clay properly prepared. For this purpose I calcine my clays, and reduce them into small pieces, which I spread over the floor of my leaden chambers. The sulphuric acid, which is formed by the combustion of a mixture of sulphur and saltpetre, expands itself in the cavity of these chambers and exists for a certain time in the vaporous form. In this form it has a stronger action than when it has been weakened by the mixture of a quantity of water more or less considerable: so that it seizes the earths, combines with them, causes them to increase in bulk by the efflorescence which takes place, and at the end of several days the whole surface exposed

to the vapour is converted into alum. Care is taken to stir these earths from time to time, that they may successively present all their surfaces to the action of the acid.

But whatever process may be used to combine the acid with clay, it is necessary to expose the aluminized earths to the air during a greater or less space of time, in order that the combination may be more accurate, and the saturation more complete.

Most of the alum in commerce is afforded by ores which are dug out of the earth for this purpose.* We may reduce all the operations of this manufacture to three or four; the decomposition of the ore, the lixiviation of the ore, the evaporation of these lixiviums, and the crystallization of the alum.

1. The decomposition of the mineral is effected either in the open air without assistance, or else by means of fire.

When the mineral is left to decompose spontaneously, nothing more is done than to dispose the stone which contains the principles of alum in strata or layers. The pyrites becomes heated; acid is formed, which dissolves the clay; and the salt arising from this combination exhibits itself by the efflorescence of the ore. The decomposition may be accelerated by watering the heap of pyrites; but the operation may be still more abridged by the assistance of fire.—The method of applying the heat varies prodigiously. On this head Bergmann may be consulted; but in general it may be observed that it ought not to be either too strong or too weak. In the first case it volatilizes the sulphur, and in the second it retards the operation.

The ore of alum is sometimes impregnated with a sufficient quantity of bitumen to maintain the combustion.—See my Memoir on the Alum Ore of Vabrais, 1785.

2. When the ore has effloresced into alum, the salt is extracted by lixiviation. For this purpose the same wa-

* Alum is said to be found in great quantities, near Fort Pitt, in Pennsylvania; in the townships of Barrington, Orford and Jaffrey, New-Hampshire;* on the Shawangunk mountain, in New-York.† and in the upper parts of South-Carolina.‡—*Am. Ed.*

* Belknap, vol. iii. p. 194.

† Med. Repository, Hexade ii. p. 194.

‡ Drayton.

ter is passed over several heaps of aluminous earth, in order to saturate it. The water which is first passed over the earth dissolves in preference the vitriol, which is more or less abundant; and this salt may be separated from the alum by a previous cold-washing.

3. This lixivium, or saline solution, is carried into leaden caldrons, where the fluid is properly concentrated. In this part of the process it is that an accurate saturation of the alum is effected when the acid is in excess; and for this purpose alkalis are added, which serve likewise singularly to facilitate the crystallization. The celebrated Bergmann has proposed to boil clay with the solution, to saturate the excess of acid. This process seems in every point of view to be advantageous; but it appears to me to be impracticable, because the superabundant acid cannot be made to combine with the clay but by a very long ebullition; and I have observed that, by afterwards evaporating the fluid to cause it to crystallize, this clay falls down, and opposes the crystallization. I have varied the process in a variety of ways, without obtaining the success which its celebrated author predicted.

There are methods of greater or less accuracy to judge of the degree of concentration to which it is proper to carry the lixivium; in order to obtain a good crystallization: such are, the immersion of an egg in the liquid, the effusion of some drops of the lixivium on a plate, &c. Mr. De Morveau has proposed a metallic hygrometer; but this instrument cannot be considered as very accurate, because its immersion in the liquid is proportional to the heat of the fluid in which it is plunged.

4. The lixivium is then conveyed into coolers, where it crystallizes by mere refrigeration. The pyramids of alum are constantly turned towards the bottom of the vessel, more especially those which fix themselves to the sticks which are put into the liquor to multiply the surfaces.

Alum affects the form of two tetrahedral pyramids, applied to each other, base to base. Sometimes the angles are truncated, and these truncatures take place most frequently when the lixivium is slightly too acid.

This salt requires fifteen times its weight of water to dissolve it, at the temperature of 60 degrees of Fahrenheit, according to Kirwan.

Its taste is styptic; it loses its water of crystallization by heat; at the same time that it swells up, and is converted into a light and white substance, called burned or calcined alum.

If it be urged by a violent degree of heat, it loses part of its acid, and becomes tasteless. The residue is no longer susceptible of crystallization, and precipitates in the form of a very fine adhesive powder, in proportion as the water is dispersed by evaporation.

Alumine is precipitated from this solution by magnesia, barytes, and the alkalis: these last dissolve the precipitate in proportion as it is formed, if they be added in excess.

Alum is a very valuable material in the arts. It is the soul of the art of dying, and serves as the mordant to all colours. It is used to prepare leather, to impregnate paper and cloths intended to be printed. It is added to tallow, to render it harder; it enters into the preparation of a glue for the destruction of vermin; it is employed in England, and elsewhere, to give whiteness and additional weight, to bread. When fused with saltpetre of the first boiling, it forms a very white crystal mineral.

The printers rub their balls with calcined alum, to cause them to take the ink. Surgeons employ it to corrode fungous or proud flesh.

SPECIES II.

Carbonate of Alumine.

The argillaceous earth precipitated from the solution of alum by the carbonates of alkalis, combines with their acid; but this salt is very rarely found in nature. I know only of the observation of Schreber which ascertains its existence. This naturalist asserted that the earth known by the name of Lac Lunæ is a true carbonate of alumine.

Although alumine be soluble in the other acids, we are very little acquainted with its combinations. It is only known that the nitric acid dissolves it, that the solution is astringent, and that it may be obtained in small styptic and deliquescent crystals.

The muriatic acid has a more evident action upon alumine. This muriate is gelatinous and deliquescent.

These salts have not been applied to any use, and they are no where found in nature.

GENUS V.

Earthy Salts with Base of Silex.

Silex is of all the known earths that which combines the most difficultly with acids.

We are even acquainted with no other acid than the fluoric which exerts an evident action upon it. It rises with it, and holds it in solution until it abandons it to unite with water.

Some experiments of Mr. Achard gave reason to think that the carbonic acid dissolved silex; but the Parisian chemist did not obtain the results announced by the chemist of Berlin. M. De Morveau seems to have proved that iron and the carbonic acid were necessary to form rock crystals: but this acid does not remain united and combined with the earth; so that we have not hitherto arrived at any proof of its dissolving virtue.

CLASS II.

Concerning the Combination and Mixture of Primitive Earths, or Earthy Mixtures.

The pure and simple earths, such as we have described them, are rarely found on the surface of the globe. They are constantly mixed with each other, and form masses of greater or less magnitude, and various hardness, according to the nature of the earths, their state of division, and the character of the foreign substances which are combined with them, such as iron, bitumens, &c.

It may be easily understood that the number of compositions which can result from the mixture of five primitive earths, would be infinite, if we were to pay attention to such slight varieties as depend on the proportions of the mixture: but I shall not consider any mixtures as consti-

tating species truly distinct, except such as differ in the identity of their constituent principles. The slight differences in the proportions of these principles may indeed occasion modifications in the form, the hardness, the colour, &c. But these can never constitute more than varieties.

We shall naturally deduce the genus from the stone or earth which predominates in any mixture, and appears to communicate its own character to the total mass. In this manner we shall class among the calcareous mixtures such stones as exhibit to our observation the properties of limestone to such a degree, that they would be taken to be purely calcareous if the chemical analysis did not prove the existence of other principles.

The genus ought not in strictness to be taken and deduced from the earthy principle which predominates; for the character of the whole mass or of the mixture, is very frequently given by an earth which does not form the most abundant principle; as we observe more especially in magnesian earths, where the silex predominates over the magnesia.

GENUS I.

Calcareous Mixtures.

According to the principles we have laid down, we must refer to this place those stony mixtures in which the properties of lime-stone predominate.

SPECIES I.

Lime-stone and Magnesia.

This mixture is very common; almost all the calcareous stones contain magnesia. Mr. Bayen has described a variety in the *Journal de Physique*, t. xiii. which contain in the hundred parts seventy-five carbonate of lime, twelve magnesia, and thirteen iron: it is the earth of Crentzwald. Mr. Woulfe has described another variety in the *Philosophical Transactions* for 1779. It afforded

sixty parts carbonate of lime, thirty-five carbonate of magnesia, and three of iron.

The analyses which I have made of several lime-stones in our province, constantly afforded magnesia.

SPECIES II.

Limestone and Barytes.

Mr. Kirwan has informed us that this species is found in Derbyshire, in the form of a stone, and likewise in the earthy state. It is of a grey colour, and harder than ordinary lime-stones.

SPECIES III.

Carbonate of Lime and Alumine.

This mixture is frequently met with. It is commonly known by the name of Marl. The proportions of the two constituent principles are infinitely various. It is upon this proportion that the distinction of fat marls and lean marls depends, and disposes them to serve as manure for earths of different kinds. The marls are almost always coloured by iron.

They appear to arise from the decomposition of the natural mixtures of chalk and clay, and contain more or less of silex; but the analysis which I made six years ago of all the marls I could procure, convinced me that they were often nothing more than a mixture of clay and chalk. I have likewise found magnesia in marls, sometimes in the quantity of seventeen parts in the hundred; but, in general, they may be considered as formed essentially by the two earths here mentioned.

Alumine is found likewise mixed with carbonate of lime in marbles. Mr. Bayen has proved this in the second volume of the *Journal de Physique*: and I have confirmed the truth of his results by the analysis of several marbles of our province. It is even upon this principle that we may account for the greasy polish which some of them take.

The very evident difference which may be established between the mixtures which form marl and marble, is, that the first is the immediate product of a decomposition principally effected by the alterations of the iron which it

contains; whereas, the second is produced by a purely mechanical mixture of two principles already formed, which being pounded, and ground as it were together, form a compact, hard, close assemblage, susceptible of the most beautiful polish.

SPECIES IV.

Lime-stone and Silex.

This species is not common. It is known under the name of Stellated Spar, Stern Schoerl of the Germans. It is opaque, of a radiated texture or form. Mr. Fitchel found it in lime-stone on the Carpathian mountains. It effervesces with acids; and, according to Mr. Bindheim, one hundred parts of this stone contain sixty-six carbonate of lime, thirty silex, and three iron.—See Kirwan.

The mixture of the pulverulent remains of the primitive rocks transported into our country by the rivers which rise in the Alps and the Cevennes, together with our own calcareous fragments, frequently form beds of a stone of this nature. The only difference between them is, that our mixtures exhibit a confused assemblage of all the principles which belong to the primitive rocks, such as clay, silex, and others.

SPECIES V.

Limestone and Bitumen.

This mixture is known by the name of Swine-stone. It abounds in the diocesses of Alais and Uzes: I have seen the calcareous rock impregnated with bitumen in an extent of more than three leagues diameter. It is even so abundant in some parts, that it distils through the clefts of the rocks, and forms stalactitious bitumen, which the peasants collect to mark their sheep, or to grease their cart-wheels. The heat of our summer sometimes softens it to such a degree, that it flows into the roads, where it adheres to and impedes the motion of the sledges and other carriages.

In some places the stone is so well impregnated with bitumen, that it may be wrought; but the blow of a hammer causes it to emit an abominable smell. Mr. D'Avejan, bishop of Alais, having used this stone to pave the apartments of his palace, the friction and heat disengaged so unpleasant a smell, that his successors were obliged to substitute a stone of another kind in its stead.

Mr. De la Peyrouse found this stone in large masses near Saint Beal in Comminge, at L'Estageau, and the mill of Langlade.

SPECIES VI.

Lime-stone and Iron.

Iron is almost always a constituent part of lime-stone; but it sometimes exists in such a proportion, that these mixtures constitute iron ores. Mr. Kirwan describes two of this nature; one of which contains twenty-five pounds of iron in the quintal, and the other ten. Mr. Rinmann has described stalactites which afford iron, in the proportion of from twenty-seven to twenty pounds in the quintal.

Calcareous iron ores are wrought in many parts of our province. I have myself obtained forty-four pounds of iron in the quintal, from a calcareous stone which abounds on the mountain of Frontignan.

It is common to find, in our calcareous mountains, hematites rich in iron, whose base is calcareous; we find likewise species of ludus of the same genus, and sometimes even tufa, whose formation arises from waters loaded with iron and lime.

The spathose iron ores are of the same class as those we have just treated of.

GENUS II.

Barytic Mixtures.

These mixtures are very rare, because the stone itself is scarce. We shall mention only two species.

SPECIES I.

Sulphate of Barytes, Petroleum, Gypsum, Alum, and Silex.—*Bergmanni Sciagr. s. 90; Kirwan Min. p. 60.*

The name of Hepatic Stone (*Lapis Hepaticus*) has been given to this mixture.

The colour varies much: its texture is uniform, lamellated, scaly, or sparry. It takes the polish of alabaster.

It forms a kind of plaster by calcination, and emits a strong and fetid smell by friction.

One hundred parts of this stone contain thirty-three barytes, thirty-eight silex, seventeen alum, seven gypsum, and five petroleum.

SPECIES II.

Carbonate of Barytes, Iron, and Silex.

Mr. Kirwan has mentioned this stone on the authority of Mr. Bindheim. It is insoluble in acids, and of a sparry texture; but he is tempted to consider it as a sulphate of barytes, in consequence of the property observed by Mr. Bindheim, that it becomes soluble in acids, after having been calcined with oil.

GENUS III.

Magnesian Mixtures.

All the species comprised in this genus possess characters sufficiently striking, and easily known. They are in general greasy and soft to the touch; they may be cut with a knife, turned in a lathe, and converted into any form at pleasure. They take a tolerably good polish. Some of them are disposed into fibres; and these fibres possess for the most part, a remarkable degree of flexibility. They

stick to the tongue like clays; but do not, like them, soften in the water.

SPECIES I.

Pure Magnesia, Silex, and Alumine.

SPECIES II.

Carbonate of Magnesia, Silex, and Alumine.

The mixture of these three earthy principles forms talks, steatites, pot-stones, or lapides ollares.

The difference which analysis shews between these two species, is almost entirely confined to the proportions of their constituent principles. This circumstance might appear sufficient to authorize us in considering them only as varieties of each other. But as the magnesia is pure in the talk, and in the state of carbonate in the steatites, we shall consider them as different species.

1. Pure magnesia, mixed with near twice its weight of silex, and less than its weight of alumine, forms talk. It is of a white, grey, yellow, or greenish colour : soft and soapy to the touch, composed of transparent laminæ placed upon each other. These laminæ are more tender than those of mica; they lock together, and are usually divided into rhombi, and may be crushed or scratched with the nail.

Its specific gravity is 2.729.

Fire renders it more brittle and white; but it is infusible by the blow-pipe, and can scarcely be fused by the addition of alkali. The borate of soda, and the phosphate of urine, fuse it with a slight effervescence.

Muscovy talk is composed of large elastic, flexible, and transparent leaves. Plates of talk have been raised in the quarries of Vitim in Siberia which were eight feet square.*

* Talk is found in New-Hampshire, adhering to rocks of white or yellow quartz, and lying in laminæ like sheets of paper. The most of it is white, some is yellow, and some has a purple hue. The larg-

2. Steatites is usually of a greenish white: it may be easily cut with a knife; and the dust which is produced by scraping it does not readily mix with water.

Its specific gravity is about 2.433.

It is infusible alone, hardens in the fire, and becomes white. The borate of soda facilitates its fusion; but soda, and the phosphates of urine, do not perfectly dissolve it.

According to the analysis of Bergmann, one hundred parts of steatites contain eighty silex, seventeen magnesia, in the state of carbonate, two alumine, and one iron.

Steatites is sometimes found in masses of indeterminate figure, and sometimes crystallized, such as that which Mr. Gerhard found at Raichewtein in Silesia. Chem. Ann. 1785.—And Mr. Romé de Lisle possesses crystals in hexagonal laminæ resembling the leaves of mica.

The white steatites of Briançon is composed of irregular, friable, and semi-transparent leaves. It often incloses crystals of steatites, of a white or greenish colour, which have the form of tetrahedral prisms.

The steatites of Corsica appears to be formed by fibres placed beside each other. It has a greenish colour, and no perceptible degree of flexibility.

The steatites of Bareith is grey, compact and solid.

est leaves of this curious substance are found in a mountain, in the township of Grafton, about twenty miles eastward of Dartmouth college. It was first discovered in the following manner: A huntsman took shelter for the night, in a cavern of the mountain, and in the morning found himself surrounded with this transparent substance, a large leaf of which he fastened to the branch of a tree, near the cave, as a mark by which he might again find the place. This happened during the revolutionary war, when window-glass could not be imported. The scarcity of that article, brought the talk into repute. Many persons employed their time in blowing the rocks, separating the laminæ, cutting them into squares, and vending them about the country. This substance is particularly valuable for the windows of ships, as it is not brittle, but elastic, and will stand the explosion of cannon. It is also used to cover miniature paintings, and to preserve minute objects for the microscope. The disadvantage of it for windows is, that it contracts dust, and is not easily cleaned, but for lanterns it is preferable to glass. (Belknap's History of New-Hampshire, vol. 3, p. 193.)

The rocks of granite near Philadelphia are interspersed with talk, often of a black colour.—*Am. Ed.*

That of Queen Charlotte's Bay in New Zealand is striated, green, semi-transparent, and sufficiently hard to give fire with the steel.

3. The soap-stone of China is a steatite, often striated; but it is not more unctuous than those we have already mentioned.

The steatites of Briançon forms the basis of the vegetable red.*

4. The lapis ollaris, or pot stone, is only a variety of the steatites. It does not appear to me to differ from it, excepting in being harder.

Its colour is usually greyish; but it is sometimes blackened by bitumen.

Mr. Gerhard has observed that the lapis ollaris of Sweden effervesces with acids, and contains calcareous earth; but this mixture is peculiar to it. Those of Saxony, Silesia and Corsica, do not contain it. The lapis ollaris may be wrought with the greatest facility. In the country of the Grisons, in Corsica, and elsewhere, it is turned, and formed into vessels which resist the fire, and have not the inconvenience of our glazed pottery; it is from these uses that it has obtained the name of Lapis Ollaris, Pot Stone, &c.

SPECIES III.

Pure Magnesia combined with somewhat more than its weight of Sillex, one-third of Alumine, near one-third of Water, and more or less of Iron.

This mixture forms the serpentine. It has a great analogy with the preceding substances, but is distinguished from them by a more evident degree of hardness; by the property of acquiring a more beautiful polish; and by a quantity of iron sufficiently considerable to afford it a peculiar character.

* Steatites is found fifteen miles from Philadelphia, on the banks of the Schuylkill; in South-Carolina, in the neighbourhood of Hill and Haynes' iron works; and at Orford on Connecticut river, New-Hampshire. Belknap says, it has the property of fullers' earth in cleaning cloths.—*Am. Ed.*

The serpentine is whitish, greenish, blueish, or blackish; frequently marked with black spots; and sometimes intersected with bands of various colours. Some serpentines are even transparent. The Royal Cabinet of Mines possess a specimen whose ground is grey, and interspersed with reddish semi-transparent and chatoyant spots.

Serpentine varies likewise in its texture.

It is compact, granulated, scaly, lamellated, or fibrous. It takes the most beautiful polish.

The iron it contains is sometimes obedient to the magnet.

Its specific gravity is from 2.4 to 2.65.

It melts in a violent heat; but a less degree of fire hardens it.

Mr. Bayen, who has analyzed the serpentine, found it to contain, in the hundred parts, forty-one silex, thirty-three magnesia, twenty alumine, three iron, and also water.

Mr. Kirwan has observed, that the serpentine of Corsica, contained more alumine, and less silex.

Mr. De Joubert possesses a species of serpentine which exhibits square plates on its surface.

Mr. Dorthes has observed several varieties of the serpentines on our Mediterranean coasts, and in the river of Herault, which receives them from the mountains of the Cevennes.

SPECIES IV.

Carbonate of Magnesia; Silex, Lime, Alumine, and Iron.

This combination exhibits several varieties, which are known under the name of Asbestos, Mountain Cork. Their texture serves to distinguish them; but the chemical analysis confounds them together, and does not permit us to allow any other distinction than that of varieties.

VARIETY I.

Asbestos.

This stone is usually greenish; its texture is sometimes fibrous and compact, and sometimes membranaceous.

Near Bagnères de Bigorre, in the mountains of the environs of Bassere, Messrs. Dolomieu and La Prouse found crystals of asbestos in rhomboidal parallelepipeds.

Asbestos is rough to the touch, brittle and rugged. Its specific gravity is from 2.5 to 2.8.

Fire renders it whiter and more brittle. It is infusible by the blow-pipe, according to Kirwan; but the abbé Mongez affirms that asbestos and amianthus are fusible, and form an opaque globule, which becomes blueish. It is difficultly soluble with soda; but more easily with borate of soda and the phosphates of urine.

According to Bergmann, the asbestos contains in the quintal from fifty-three to seventy-four parts silex, about sixteen magnesia, from twelve to twenty-eight carbonate of lime, from two to six alumine, and from one to two iron.*

VARIETY II.

Mountain Cork.

This name has been given on account of a slight resemblance of this substance to cork. This stone is very light, membranaceous, flexible, and usually of a yellow colour. It may be more easily torn than broken. The diocese of Alais affords very fine specimens.

Among a very great number of stones of this nature, subjected to analysis by the celebrated Bergmann, the siliceous earth was always found predominant; and after

* Asbestos is found in Chester county, Pennsylvania; in the state of New-York, and at the head waters of Lynch's creek, South-Carolina.—*Am. Ed.*

that the magnesian, which was never less than twelve parts in the hundred, nor more than twenty-eight.

SPECIES V.

Carbonate of Magnesia and Lime, Sulphate of Barytes, Alumine, and Iron.

This combination forms amianthus. It is composed of long flexible fibres, parallel to each other, and very soft to the touch.

They are sometimes very white, but often yellowish. The filaments may be separated and detached from each other; and may be even twisted in any direction without danger of breaking them. Their flexibility is so wonderful, that they may be formed into cloth. The ancients constructed cloths of this kind, in which they burned the bodies of the dead; and by this means the ashes were collected without mixture of those of the fuel.

Mr. Dorthes found amianthus in tufts upon calcareous stones thrown up by the sea, on which it was fixed with plants, corallines, gorgonia, &c. He believes, with reason, that this amianthus did not originate upon the stones, but that it was deposited by the water. He found, likewise, on the coast, balls of the amianthus of two or three inches diameter imitating ægagropiles, and formed by the intertwining of the threads of amianthus; and covered with a white tophose substance, of the nature of that which covers the gorgonia, and is the work of a species of sea animalcule.

The fibres of amianthus are of various lengths. I have received specimens from Corsica, whose filaments were very flexible, and eight inches long. That from the Pyrenean mountains has shorter fibres.

Bergmann analyzed an amianthus from the vicinity of Tarento, of which 100 parts afforded 64 silex, 18.6 magnesia, 6.9 lime, 6 sulphate of barytes, 3.3 alumine, 1.2 iron.

GENUS IV.

Aluminous Mixtures.

Argillaceous or aluminous stones are common enough. They are seldom possessed of more than a moderate degree of hardness, and are divisible in water. But the mixture of their principles is in some instances so intimate, that they possess a very strong degree of consistence.

SPECIES I.

Alumine, Silex, Carbonate of Lime, and more or less of Iron.

We may here place all the varieties of clay. Chemical analysis exhibits constantly enough the principles whose mixture forms this species; but the proportions among these constituent principles vary so much, that the varieties of clay are almost infinite. Independent of the principles above enumerated, we sometimes find lime combined with clay, and sometimes even magnesia; and it will be easy to form various species, in proportion as the analysis of these earths shall become more perfect.

The argillaceous mixtures of which we propose at present to speak, are characterized by the following properties:—They adhere strongly to the tongue, become dry, hard, and shrink in the fire; are divided, and form a paste, with water, in which state they may be easily moulded and turned, &c. The clays in which the siliceous principle is most abundant are the driest, adhere less to the tongue, are less completely diffused in water, and crack less when dried by the heat of the fire or the sun.

Most clays contain iron; and this metal is usually the principle of their colour. From the brownish clay, in which iron is almost in the native state, to the deepest red, all the various shades are owing to the several degrees of alteration in this metal. These various changes

are effected either at the surface of the globe by the immediate action of the air, which calcines the iron, or else in the bowels of the earth; in which last case, the effects arise from the decomposition of water and of the pyrites. We may trace this beautiful work of nature in several pyritaceous strata in our province; and on this subject reference may be had to my Memoir upon the Brown Red (Brun Rouge), printed by Didot by order of the province.

We shall direct our attention less to the several varieties of clay than to the uses to which they are applied. The first of these uses is to form the basis of pottery.

Several species of pottery may be observed, which nevertheless differ from each other only in the degree of fineness of the earths made use of, and the care that has been taken in performing the various manipulations which they undergo.

1. The most common pottery is made with any kind of clay indiscriminately, which is mixed with sand, to render it more porous, and by this means more adapted to support the heat.

These vessels would be penetrable by water, if they were not covered with a glaze.

The glazes of pottery are usually made either with the sulphureous lead ore, called Alquinfoux, and in England, Potter's Lead Ore, or with the yellow copper ore. For this purpose, these substances are reduced to powder, mixed with water, and the vessel, previously dried by a slight baking, is dipped in the mixture. The porous vessel absorbs the water, while its surface becomes covered with the pounded ore. The vessel is then carried to the furnace, and baked by a heat which vitrifies the ore upon its surface: and it is this metallic glass which forms the glaze of the potters, and is yellow or green, according to the metal made use of.

These glazes are all dangerous; because they are soluble in fats, oils, acids, &c.

The attention of intelligent manufacturers has been long directed to the methods of substituting in the place of these glazes, others which are not attended with the same danger.

We might, after the manner of the English, vitrify the surface of our pottery by means of sea salt thrown

into the fire-place when the furnace is at a white heat ; but this method is impracticable in most of our manufactories, because our fires are not sufficiently strong.

I have tried various methods to glaze pottery ; and two among them have succeeded well enough to justify my publishing them. The first consists in mixing the earth of Murviel in water, and dipping the pottery therein : this done, they are suffered to dry ; after which they are plunged into a second water, in which levigated green glass is mixed. This covering of vitreous powder fuses with the clay of Murviel ; and the result is a very smooth, very white, and very cheap glazing.

The second method consists in immersing the dried pottery into a strong solution of sea salt, and afterwards baking them. The trial which I have made in my furnaces gives me reason to expect that this method may be used in large works.

I have likewise obtained a very black glazing, by exposing pottery strongly heated to the fumes of sea-coal. I have coated several vessels in this manner, by throwing a large quantity of coal in powder into a furnace wherein the pottery was ignited to whiteness. The effect is still more complete when the chimneys or tubes of aspiration of the furnace are at that moment closed, and kept so for some minutes.

I have given an account of all these circumstances, and many others, in a work presented to the Royal Society of Sciences of Montpellier ; in which I have proved, from the results of my experiments in the large way, that the best mixture of our own earths is capable of affording us the most beautiful and finest pottery of every kind.

2. Fayence*. This does not differ from the pottery we have here spoken of, except in the degree of fineness of the earths used for this basis, and the nature of its covering or glaze.

The glazing of fayence is nothing else, as is well known, but glass rendered opaque by means of the oxide of tin. It is the glass called Enamel.

To make the fine white enamel of the potters, one hundred pounds of lead, thirty of tin, ten of marine salt,

* Distinguished by us by the name of Delft Ware. T.

and twelve of purified potash, are calcined together. This mixture, after calcination and fusion, produces a beautiful enamel, which is applied in the same manner as the glaze before spoken of.

Bernard de Palissy excelled in the art of fayencery; and it is to him that we are indebted for our first acquisitions in this manufacture.*

* I cannot resist my inclination to insert in this place a few circumstances of the life of this great but unfortunate man, who lived in the 15th century. He was a native of the diocese of Agen, and his first employment was that of surveyor or draftsman of plans: but his taste for natural history led him to abandon this employment; and he travelled for instruction over the whole kingdom, and Lower Germany. An accidental circumstance threw into his hands a cup of enamelled pottery; and, from that time, his whole time and fortune were taken up in experiments on enamels. Nothing can be more interesting than the narrative which he himself has given of his labours. He exhibits himself building and rebuilding his furnaces; always on the eve of success; worn out by labour and misfortune; the derision of the public; the object of the angry remonstrances of his wife; and reduced to burn his furniture, and even the wood-work of his house, to keep his furnace going. His workman presses him for money: he strips himself, and gives him his clothes. But at length, by dint of indefatigable labour, constancy and genius, he arrived at the desired degree of perfection; which gained him the esteem and consideration of the greatest men of his age. He was the first who formed a collection of natural history at Paris, and even gave lectures on that science; receiving half a crown from each of his auditors, under the obligation of returning it fourfold if any thing he taught should prove false. The high reputation he acquired, and the obligations under which his countrymen stood indebted to him, were not sufficient to defend him from the persecutions of the league; for Matthew De Launay, one of the greatest fanatics, caused him to be dragged to the bastille at the age of ninety years. He signalized himself in his prison by acts of firmness and heroism. Henry the Third visited him, and represented his situation in these words: "My good man, if you cannot reconcile yourself to the matter of religion, I shall be compelled to leave you in the hands of my enemies."—Palissy answered, "Sire, I was perfectly ready to surrender my life for the glory of GOD. If this action could have been accompanied with any regret, certainly it must have vanished after hearing the great King of France say, *I am compelled*. This, sire, is a situation to which neither yourself, nor those who force you to act contrary to your own disposition, can ever reduce me; because I am prepared for death; and because neither your whole people, nor your Majesty, possess the power of forcing a simple potter to bend his knee before images."—Bernard de Palissy was the first who affirmed that calcareous mountains are the

3. The finest pottery is known by the name of Porcelain; it ought to be white, transparent, and of a fine grain.

The first porcelains were manufactured in Japan and China.

The celebrated Reaumur first undertook a capital series of experiments to imitate these potteries: but, deceived by the semi-transparence and vitreous appearance of porcelain, he imagined it to be a semi-vitrification, and attended only to the means of stopping the process of vitrification at a certain stage of its effect, or of causing it to become reversed. He succeeded in his undertaking, by filling bottles with sand and gypsum, and exposing them to a potter's furnace. I have likewise produced the same effect by a very different process, though dependent on the same theory. When I concentrate my oil of vitriol in the green glass of our manufacture, that part of the retort which is continually struck by the rising oil of vitriol becomes white, and loses its transparence. This phenomenon constantly takes place, whenever the fire is raised somewhat more than usual. The retort preserves its form; but all its alkali is extracted, and there remains only the quartzose principle of a beautiful white colour, somewhat cracked like the porcelain of Japan. As the decomposition commences at the interior surface, which is immediately acted on by the vapours, this surface is frequently rendered white, and discoloured; while the exterior surface remains perfectly vitreous, and exhibits a striking contrast. For, when the interior surface of the glass is inspected, it presents a white covering applied against a surface of glass; forming, by the union of both, a thickness no greater than that of which retorts are usually made.

Father Dentrecolles sent from China the substances used in the fabrication of porcelain: they are known by the names of Kaolin and Petunzé. Similar substances

remains of shells. He has exhibited such a degree of intelligence and sagacity in all his writings, that he deserves to be placed among those great men who are an ornament to our nation. The very form of his works exhibits a proof of original genius. They consist of dialogues between Theory and Practice. Practice is always the instructor; and Theory is represented as a scholar, proud of his own understanding, but indocile and ignorant.

were soon found in France; and our porcelain manufactories, in a short time, equalled the most beautiful productions of this kind, and even exceeded them in the beauty of design and figure. The manufactory of Sèvres is at present, without contradiction, the first in the world. Nothing can equal the beauty of its paintings, the regularity of design, and the elegance of form, which are given to the vessels produced in this manufactory.

Four principal operations may be distinguished in the manufacture of porcelain.—1. The preparation, the mixture of earths, and the working of the paste. 2. The first baking, which forms the biscuit. 3. The application and fusion of the glaze and covering. 4. The art of painting, which demands a third baking, in order that the colours may be better combined, fused, and amalgamated with the glaze.

I have myself made very beautiful porcelain with the kaolin, which is found in veins in the granite of St. Jean de Gardonnenque, and the field spar so common in our mountains of Cevennes.

The quantity of porcelain which is made in China is immense. There are five hundred furnaces, and near a million of men, employed at King-to-ching, a province of Kian-si.

Our clays possess other advantages likewise: they serve in the fulling-mills to clean and full piece goods. The best fuller's earth is soft and soapy.

The name of tobacco-pipe clay is given to a white clay, which preserves its whiteness in the fire, and resists a violent heat.

The scaled earths, or *terræ sigillatæ*, are clays upon which superstition has bestowed chimerical virtues. They are impressed with a seal, for the purpose of deceiving the public with greater certainty and effrontery.

Almost all the marls, more especially those which are found in strata, appear to me to be composed of the same principles. Much variation prevails with respect to the proportion of those constituent principles. and more especially with regard to the clay which predominates.*

* A variety of good clays are found in the United States. Excellent porcelain earth is met with on the banks of the Delaware,

SPECIES II.

Alumine, Silex, Pure Magnesia, and Iron.

Mica, which results from the mixture of these principles, has been improperly confounded with talk. Mica is soft to the touch, but not greasy like talk. It possesses in general a more brilliant and less earthy colour, if I may use these expressions.

The most usual colour of mica is white or yellow, inclining to red; but it has been found of a greenish, red, brown, and other colours.

Its texture likewise varies: it is scaly, lamellated, or striated.

It sometimes exhibits the form of a segment of an hexagonal prism.

It is usually found mixed with feld spar, quartz, schorl, &c. It almost always exists in the primitive rocks. Its specific gravity is from 2.535 to 3.000 when charged with iron.—Kirwan.

The colourless mica is infusible. It is only partially soluble in soda, in which it becomes divided with effervescence: it fuses in the borate of soda, and in the phosphate of urine, with scarcely any effervescence.

The coloured micas are fusible.—See De Saussure.

The fragments of mica are employed, under the name of Cats Gold or Silver, according to the colour, as a sand for drying ink upon paper.

Its yellow colour, which considerably resembles that of gold, often deceives the ignorant, who suppose that they have discovered a mine of this precious metal when they find a few pieces of this stone.

above and below Philadelphia, and in Maryland near Hagerstown, at the foot of the Ketoc-ton mountain. China of a fine quality was made in Philadelphia before the revolutionary war. Most of our clays contain iron; hence they burn of a yellow and red colour. Bricks for furnaces, or fire bricks, are manufactured from the porcelain earth of the Delaware, mixed with decomposed granite, containing a large portion of mica, found near Gray's ferry on the Schuylkill; and crucibles for glass houses are made of the same earth, and old burnt crucibles, in coarse powder.—*Am. Ed.*

Mr. Kirwan obtained from one hundred parts of colourless mica, thirty-eight silex, twenty-eight alumine, twenty magnesia, and fourteen oxide of iron.

SPECIES III.

Alumine, Silex, Magnesia, Lime, and Iron.

The mixture of these principles forms the horn-stone, or horn-blende of the Germans. This stone has a close grain, is difficultly pulverized, and is slightly flattened under the hammer.

Its colour varies, which is either black or of a greenish grey; and its texture is in general either lamellated or striated.

Its general characters are, partial solubility in acids without effervescence; a degree of hardness which never amounts to that of affording fire with the steel; a specific gravity never less than 2.66, and frequently as high as 3.88; a strong earthy smell, which it emits when breathed upon, or is moistened with hot water; a tenacity under the pestle, &c.—See Kirwan, who distinguishes two varieties.*

VARIETY I.

Black Horn-stone, Lapis Corneus Nitens Wallerii.

Its texture is either lamellated or grained. In the first case it is sometimes so soft as to be capable of being scratched with the nail. Its surface is frequently of a shining, greasy appearance; and its specific gravity is from 3.6 to 3.88.

Mr. Kirwan found that the lamellated sort contains thirty-seven parts silex, twenty-two clay, sixteen magnesia, two lime, and twenty-three oxide of iron.

* Horn-blende of several varieties is found in the granite of the United States.—*Am. Ed.*

VARIETY II.

Horn-stone of a greenish grey Colour.

This variety is either of a granulated or striated texture. Mr. Kirwan found its specific gravity to be 2.683; it is harder than the preceding.

The pale greenish hone is of this quality. Its grain is close; it emits an earthy smell, does not effervesce with acids, nor strike fire with steel. It contains, according to Kirwan, sixty-five parts of silex to the hundred, and its specific gravity is 6.664.

SPECIES IV.

Alumine, Silex, Carbonate of Magnesia, and of Lime with Iron.

This species, which comprehends the slate or schistus, does not appear to differ essentially from the preceding, since its principles are the same, and there is no other difference excepting what depends on the state of the lime and magnesia; which in this last effervesces slightly with acids, according to Kirwan.

The slate is an argillaceous stone, whose principal character is that of being divisible into very thin plates, capable of being wrought, and of receiving a certain polish.

The colour of the slate is blue, of several degrees of intensity; but this colour varies, and exhibits the following shades.

VARIETY I.

Blueish Purple Slate.

This is brittle, and of a lamellated texture; does not give fire with the steel; its specific gravity is 2.876; it affords a very clear and silvery sound, when divided into

plates of an uniform thickness; it slightly effervesces with acids when it is reduced into powder, but not else.

It forms black scorizæ in a strong fire. Soda assists its fusion, and it is fused still more easily with the borate of soda.

From one hundred grains of this slate Mr. Kirwan obtained forty-six silex, twenty-six alumine, eight magnesia, four carbonate of lime, and fourteen iron.

VARIETY II.

Black Slate.

This receives a considerable fine polish when rubbed. The powder which is detached is white, and slightly effervesces with acids.*

VARIETY III.

Blue Slate.

The blue slate contains less iron than the first variety. It is usually hard, and of a very fine grain.

* Mr. Drayton informs us that slate of an excellent quality, is found near the head waters of Lynch's creek, in South-Carolina. There are also immense quantities of it in the township of Rhinebeck, in Dutchess county, state of New-York. A quarry of it has also been discovered in the county of Wayne, Pennsylvania. It is on the banks of the Delaware, within three hundred yards of the river, and about seventy-five miles from Philadelphia. The rock appears on the surface of the ground, and quarries so easily, that plates several feet square have scaled off. This slate is much thinner than that of New-York, and equal to any that has been imported. Extensive use is now made of it in Philadelphia, for covering houses, as the expense is only a trifle more than that of a shingle roof.—(Mease's account of the minerals of the United States, in Wonders of Nature and Art, vol. xiv. p. 120.)

It is also found in Pennsylvania, on the river Susquehanna, and near Frederick-town, in Maryland. The Mohawk river, at the falls of Cohoos, runs over an immense bed of slate.—*Am. Ed.*

VARIETY IV.

Slate of a Pale White Colour.

It is less martial than the other varieties, and is more difficultly vitrified.

Slates are used to form tablets, and to cover the roofs of houses.

SPECIES V.

Alumine, Silex, Pyrites or Sulphure of Iron and Carbonate of Lime and of Magnesia.

The schistus which results from this combination is known by the name of Pyritous Schistus.

The pyrites are sometimes dispersed in the mass, in the form of cubical crystals. Sometimes they are discovered only by analysis, or by the spontaneous decomposition of the stone.

The mountains which afford these schisti appear to me to be marine depositions. Impressions of leaves, of fishes, and other characters, are frequently observed, which leaves no doubt of their origin.

The pyrites soon effloresce when the concurrence of air and water assists their decomposition; and the results then are sulphuric salts, with bases of magnesia, alumine, iron and lime. When the sulphate of alumine predominates, it is called aluminous schistus. Most of the alum ores wrought in Europe are of this nature. We have several in Provence which might be wrought; the schisti of Vebron in the Gevandau, those of Curvalle in the Albigeois, afford much alum by their decomposition.

When the magnesian principle prevails, the efflorescence consists of Epsom salt. I have discovered a mountain of this kind in Rouergue, in the neighbourhood of Saint Michael.

These efflorescences of alum or Epsom salt are always more or less abundantly mixed with the sulphates of iron

and of lime; because the sulphuric acid, which is formed by the decomposition of the pyrites, attacks and dissolves all the principles contained in the schistus.

The decomposition of these pyrites may be hastened by exposure to air, calcination, &c.

SPECIES VI.

Alumine, Silex, the Carbonates of Lime and of Magnesia, the Sulphure of Iron, and Bitumen.

This schistus does not differ from the foregoing, excepting in consequence of its being impregnated with bitumen. It is usually of a black colour, which it owes to its bituminous principle. Its consistence is various; it is sometimes divisible in flakes, and its surface is either smooth or rugged.

These are the schisti which usually form the focus of volcanos. When their decomposition is favoured by air or water, a prodigious heat is excited, hydrogenous gas is produced, which exerts itself against the surrounding obstacles, and takes fire when it comes in contact with the air. It is this intestine labour which occasions the shocks and tremulous agitations that precede the eruptions of volcanos. The action of volcanos must be more lasting and terrible, in proportion as the quantity of aliment and the focus are the more considerable.

We might, in strictness, place the pit-coals here, as they do not differ from this schistus but in their greater abundance of the bituminous principle. We daily observe spontaneous inflammation to take place in heaps of pyritous coal, and the same effect happens even in the midst of the veins which are wrought. Several examples of this may be pointed out in the kingdom of France. There even exists at Cransac in Rouergue a true burning volcano. The mountain which contains the coal is prodigiously hot, and flames are perceived from time to time on its summit, which issue from its bowels. All these phenomena depend on the same cause; and from the small artificial volcano of Lemery, to the terrible eruptions of Vesuvius,

there is no other difference than what consists in the magnitude of the cause.

When the earthy and metallic principles which form the basis of bituminous schisti, are strongly heated, and almost vitrified by the fire which produces their decomposition, they constitute volcanic products.

SPECIES VII.

Alumine, Silex, Lime, and Water.

This stone which is called Zeolite, was unknown to mineralogists before the celebrated Cronstedt gave a description of it.

It is usually of a semi-transparent white; but this colour is sometimes altered by metallic mixtures, and then it assumes all kinds of tinges.

The name of Zeolite has been given to it on account of its property of forming a jelly with acids. This property has even been considered as exclusive and characteristic. But Mr. Swab has very justly observed, in the year 1758, that all zeolites do not possess this property; and Mr. Pelletier has proved in the twentieth volume of the *Journal de Physique* that this property is not even peculiar to zeolites.

The existence of zeolites in certain lavas has induced some naturalists to consider them as produced by the decomposition of volcanic earths.

The most beautiful zeolites come to us from the islands of Ferroe near Iceland. The form of this stone is constant. The radii which compose it diverge as it were from a central point, and are disposed after the manner of a fan. The radius which terminates at the external surface, is found to exhibit a trihedral or tetrahedral pyramid.

The white zeolite affects two principal forms, the cube, and the tetrahedral prism, sometimes flattened, and terminated by an obtuse tetrahedral pyramid.

Its specific gravity is from 2.1 to 3.15.

The zeolite, exposed to a strong heat, dilates, and swells more or less, according to the proportion of water

it contains, and at length melts into a porous scoria. Soda fuses with it with effervescence; the borate of soda dissolves it more difficultly; and the phosphates of urine have scarcely any action upon it.

Bergmann obtained from one hundred parts of the red zeolite of Adelfort, 83 silex, 9.5 alumine, 6.5 pure lime, and 4 water.—Letters on Iceland, p. 370.

The white zeolite of Ferroe contains, according to Pelletier, fifty silex, twenty alumine, eight lime, and twenty-two water.—Journal de Physique, t. xx.

Meyer obtained from a radiated zeolite, 51.33 silex, 17.5 alumine, 6.66 lime, 17.5 water.

Mr. Kirwan rightly observes, that the crystallized species contain more water than the others.*

GENUS V.

Siliceous Mixtures.

We shall place in this genus all the stones which give fire with the steel.

SPECIES I.

Silex, Alumine, Lime, and Iron intimately combined.

The mixture of these several earths forms the precious stones or gems. All the varieties of gems depend on their colour, hardness, brilliancy, weight, the proportion of their constituent parts, and their more or less intimate combination.

The numerous experiments of the celebrated Bergmann on precious stones, have thrown the greatest light on their nature and composition. The analyses of Messrs. Gerhard, Achard, &c. by exhibiting a strict identity of

* Dr. Mitchell informs us, that zeolites have been discovered at Hoboken, New-Jersey, filling up the veins in the rocks of Stellstein and Jade which abound in that neighbourhood. Dr. Barton tells us that he has found zeolite, imbedded in crystallized basaltes, near Reading, Pennsylvania.—*Am. Ed.*

principles, have confirmed to us the results of the famous Swedish chemist; and it appears that no reasonable doubt can now be formed against those principles.

As gems or precious stones are distinguished in commerce by their colour, we shall preserve this established distinction.

DIVISION I.

Red Gems or Precious Stones—the Ruby, Garnet, &c.

1. The ruby is a precious stone of a fiery red colour, electrical by friction, giving fire with the steel, the most ponderous and the hardest of precious stones. It crystallizes in long hexahedral pyramids applied base to base, without an intermediate prism.

Its specific gravity is from 3.18 to 4.283. It is not vitrified in the fire without addition; and even resists the action of the burning mirror. Flame urged by vital air easily fuses it. It does not lose its colour at the degree of heat which is sufficient to melt iron. The borate of soda and the phosphates of urine fuse it.

One hundred parts of ruby contain, according to Bergmann, forty alumine, thirty-nine silex, nine lime, and ten iron.

The lapidaries, with whom hardness and transparency are the principal characters of stones, distinguish rubies of different colours; and the inhabitants of Pegu, who consider the modifications of the colouring principle as different degrees of maturity, confound the topaz, and the sapphire under the name of rubies, of which they make three varieties.

The name of Spinnelle ruby, or Balais ruby, is given to the same kind of stone, accordingly as its colour is of a pale or a deep red. This ruby crystallizes in octahedrons, and has a less specific gravity than the oriental ruby.

2. The garnet is transparent when it is not overloaded with iron. It is in general obedient to the magnet, and of a yellowish red. The forms of the garnet appear to be derived from the rhomboidal paralleliped, terminating in six equal rhombuses.

They vary prodigiously in colour, and these varieties are—1. The red, or the carbuncle of Theophrastus, according to Hill: it has a deep red colour. 2. The Syrian garnet, of a deep red slightly tinged with yellow. 3. The violet garnet, of a beautiful red mixed with violet.

All the garnets, whether denominated oriental or occidental, rank in one of these three classes.

Garnets change in the fire into an enamel of a blackish red. They are strongly attacked by the borate of soda, and the phosphates of urine.

Garnet is found in small grains in sand stone (gres) or in schistus.

The texture of the garnet is lamellated, and its fracture vitreous.

Its hardness is inferior to that of other gems, but it exceeds that of rock crystal.

Its specific gravity is from 3.6 to 4.188.

One hundred parts of garnet contain, according to Mr. Achard, 48.3 silex, 30 clay, 11.6 lime, 10 iron.

They sometimes contain tin, or even lead; but this is seldom.—Bergmann.*

DIVISION II.

Yellow Gems or Precious Stones—the Topaz, the Hyacinth, &c.

1. The topaz is of a gold colour. We are acquainted with two principal varieties: the occidental or Brazilian topaz, which has the beautiful deep yellow colour of gold; and the oriental, whose colour is lighter. The Saxon topaz resembles the latter.

The oriental topaz loses neither its colour nor its transparency in the porcelain furnace. The Brazilian topaz loses its polish, its hardness, and its transparency, but without melting.

The oriental topaz affects the octahedral form.

* Garnets are found in Georgia, Pennsylvania, and many of the other states. Some of them weigh four ounces.—*Am. Ed.*

The Brazilian topaz crystallizes in rhomboidal tetrahedral prisms, grooved longitudinally. They are terminated by two tetrahedral pyramids with smooth triangular faces.

The Saxon topaz exhibits long suboctahedral prisms, terminated by hexahedral pyramids more or less truncated at their base.

The specific gravity of the oriental topaz is to that of water as 40,106 to 10,000; that of the Brazilian topaz is as 35,365 to 10,000.—See Brisson.

The analysis of one hundred parts of topaz afforded Bergmann forty-six clay, thirty-nine silex, eight carbonate of lime, and six iron.*

2. The oriental hyacinth is of a reddish yellow colour.

It is usually crystallized in the form of a rectangular tetrahedral prism, terminated by two quadrangular pyramids with rhombic faces.

It loses the brilliancy of its colours by the fire. M. Mongez considers it as infusible by the blow-pipe. Mr. Achard affirms that he fused it in a wind furnace.

One hundred parts afforded Bergmann forty alumine, twenty-five silex, twenty carbonate of lime, and thirteen iron. That of which Mr. Achard has given the analysis, contained 41.33 alumine, 21.66 silex, 20 carbonate of lime, 13.33 iron.

Hyacinths are found in Poland, in Bohemia, in Saxony, Velay, &c.

The hyacinth, rendered white by fire, is known by the name of Jargon. According to Mr. Lavoisier, the hyacinth of Puy in Velay becomes white in fire urged by vital air.

Its specific gravity, compared with that of water, is as 36,873 to 10,000.—See Brisson.

* The topaz has been found in large masses in Pennsylvania and in Virginia.—*Am. Ed.*

DIVISION III.

Green Gems—the Emerald, Chrysolite, Beryl, &c.

1. The Peruvian emerald is of a green colour, electrical by friction, and crystallized in hexahedral prisms, truncated flat at each extremity.

The jaspers, or green schorles, which are called prase or mother emerald, have often been confounded with the emerald.

Crystals of emeralds are frequently found inserted in the gangues of quartz, and even of spar.

According to Mr. Sage, the more transparent emeralds are, the less their colour is changed in the fire. They become opaque, and of a greenish white. There are some which are reduced to enamel at their surface.

Mr. Darcet affirms, that in his experiments the emerald lost its transparency, and most of its colour, but that its form was not changed. In the experiments at Vienna in Austria, the emerald melted in twenty-four hours; and at Florence it was speedily fused by the burning mirror. Mr. De Saussure fused it by the blow-pipe into a compact grey glass; and Mr. Lavoisier, with a stream of vital air, fused it into an opaque milky bubble, whose interior part was greenish.

Its specific gravity, compared with that of water, is in the proportion of 27,755 to 10,000.

One hundred parts afforded Bergmann sixty alumine, twenty-four silex, eight lime, six iron.

Achard obtained 60 alumine, 21.26 silex, 8.33 lime, and 5 iron.

The emeralds which come from America are called occidental. Peru and the Brazils afford the most beautiful: they may be distinguished by the colour; that of Peru is of a satin colour or appearance; the colour of the Brazilian is less lively.

The emerald is the softest of gems, and may be scratched by the topaz, the sapphire, &c.*

* Mr. Jefferson informs us that an emerald was once found in Virginia. Dr. Seybert has discovered them at Chesnut-hill, ten miles

2. The chrysolite or peridot is of a green colour, slightly inclining to yellow.

Its form is that of a hexahedral pyramid with unequal sides, frequently striated, and terminating in two hexahedral pyramids.

Mr. Sage affirms that this stone suffers no alteration in the most violent heat; its colour not being so much as altered: and the same chemist pretends that Wallerius did not operate on a true chrysolite, because he affirms that it lost its colour. Messrs. Lavoisier and Ehrmann fused it into a white, dirty, dull-coloured glass, by the assistance of vital air.

The specific gravity of the Brazilian chrysolite is in proportion to that of water as 26,923 to 10,000.—Brisson.

Masses of granulated chrysolite of various shades of green colour are found in the prismatic basaltes, and in several other volcanic products.

These chrysolites are common in the volcanos of our province. Mr. Sage received from Auvergne an hexagonal prism six inches in diameter, formed by the union of chrysolites of different colours.

3. The beryl, or aqua marina, is of a very blueish green.

The Saxon beryl, as well as that of Siberia, sent to Mr. Sage by Mr. Pallas, exhibits hexahedral, striated, truncated prisms, of a lamellated texture.

The pure beryl decrepitates in the fire, loses its transparency, and is fusible by the blow-pipe.

Its specific gravity, in proportion to water, is as 35,489 to 10,000, for the oriental aqua marina; and 27,227 to 10,000, for the occidental.—Brisson.

from Philadelphia, and in the neighbourhood of Chester. I found one on the banks of the Schuylkill, exactly resembling the beryl of Siberia. It is transparent, and of a green colour. Dr. Chalmer's in his account of South-Carolina, says, he has seen emeralds that were brought from the country of the Cherokees, which when cut and polished fall nothing short of those which were imported from India in lustre.

The emeralds of America, generally, are similar to those of Limoge in France. They are not of a quality suited for ornaments, but may prove serviceable to the chemists, by affording glucine.
—*Am. Ed.*

A blue aqua marina, in long, flattened, tetrahedral prisms, grooved longitudinally, and united sideways, is found among the granites of Spain, and on the declivity of Saint Symphorien, near Lyon. This stone is very common at Baltimore in America.

DIVISION IV.

Blue Gems—Sapphire.

The colour of the sapphire is a sky-blue. The sapphires of the brook d'Expailly have a green tinge, and change in the fire in the same manner as those of the Brazils; whereas the oriental sapphire is not changed in our ordinary furnaces. Mr. Ehrmann caused the clear oriental sapphire, and of a perfect blue, to run into an opaque white globule by fire excited by a stream of oxigene gas.

The experiments of Messrs. Achard, Sage, D'Arcet, Ehrmann, Lavoisier, Geyx, Quist, &c. exhibit a variety of results in the analyses of gems by fire, which can be attributed only to the manner in which they applied it; and more especially to the very variable nature of the stones upon which they made their experiments.

The oriental sapphire, and that of Puy, have the form of two very long hexahedral pyramids joined and opposed base to base, without an intermediate prism. Mr. Sage saw a sapphire in a rhomboidal cube, or six-sided figure.

The sapphire analyzed by Bergmann afforded him per quintal, 58 parts alumine, 35 silex, 5 lime, and 2 iron.

Mr. Achard obtained from his analysis 58.33 alumine, 33.33 silex, 6.66 lime, and 3.33 iron.

The specific gravity of the sapphire of Puy is in proportion to water as 40,769 to 10,000; that of the white oriental sapphire is as 39,911; and that of the Brazilian sapphire is as 31,307.

SPECIES II.

Silex, sometimes pure, but oftener mixed with a very small quantity of Alumine, Lime, and Iron.

This species essentially comprehends quartz and rock crystal.

The name of Quartz is given to the opaque, or irregularly-figured vitrifiable stone; and that of Rock Crystal to the same stone crystallized. As the principles are nearly the same, this circumstance naturally establishes a division of these stones into two classes.

DIVISION I.

Rock Crystal.

Rock crystal is a stone which exhibits silex in a state more nearly approaching to purity than in any other natural substance yet observed. Mr. Gerhard has even found specimens perfectly pure; but one hundred parts of crystal, strictly analyzed by Bergmann, afforded him ninety-three parts silex, six alumine, and one lime.

The ordinary form of rock crystal is that of an hexahedral prism, terminated by pyramids of an equal number of sides. The varieties of the several crystals may be reduced to this geometrical form.—Consult Romé de Lisle.

Quartz crystallizes likewise in cubes. This form exists in various specimens in the cabinets of Germany; and Mr. Macquart brought a specimen with him to France.

The formation of this crystal appears to be owing to water, for we often find this fluid in the internal part of crystals; and they are evidently formed in the clefts and cavities of the primitive rocks, by the concurrence of this agent. But hitherto we have acquired very little knowledge respecting the circumstances of this operation.

Bergmann obtained rock crystals by dissolving silex in the fluoric acid, and suffering it to evaporate slowly. I left on the tables of my cabinet of mineralogy a receiver and a retort, in which I had made the acid of fluor; and when

I had occasion, two years afterwards, to inspect this apparatus, I found the receiver almost entirely corroded, and its interior surface lined with a subtile powder, in which thousands of rock crystals might be discerned.

Mr. Achard informed the public that he had obtained rock crystals by causing water impregnated with carbonic acid to filtrate through clay. Mr. Magellan even presented these crystals to the Academy at Paris; but the experiment, though repeated with the greatest care by several chemists of the capital, was not attended with the same results.

Since that epocha, Mr. De Morveau, having inclosed rock crystals with a bar of iron in a bottle filled with gaseous water, perceived a vitreous point fixed to the iron, which he supposed to be a rock crystal formed by this operation; so that he considers iron as a necessary intermedium to enable the carbonic acid to dissolve quartz. This consequence of Mr. De Morveau appears to agree with many facts which have been collected concerning the formation of rock crystal. We see it formed in ochreous earths; and I possess ochres in my collection which possess many of these small two-pointed crystals.

It appears to me that it is not necessary to seek for a solvent for silex, in order to explain the formation of rock crystal. The simple division of this earth appears to me to be sufficient for the purpose; and I could bring numerous facts to support this assertion.—See the article Crystallization.

It is proved by the observations and experiments of Mr. Genssane, that a quartzose guruh is formed by simple transudation upon rocks of this nature; and the same naturalist has taken notice that, when the guruh is worn and deposited by water, rock-crystals are formed. The waters which work their way through the quartzose rocks of the mine of Chamillat, near Planche Les Mines in Franche-comté, form quartzose stalactites to the roof of the works, and even upon wood. The extremities of these stalactites, which have not yet assumed a solid consistence, are of a granulated and crystalline substance, easily crushed between the fingers.

In these cavities, called *craques* by the miners, a fluid guruh is often found, and still oftener crystals ready formed.

I have seen at Saint Sauveur, in the work of La Boissiere, near Bramebiaou, several incrustations of guruh on the sides of the gallery; and these spreading incrustations were terminated by well-formed crystals, wherever the wall overhung or deviated from the perpendicular. This guruh, when handled, and minutely examined, had no other appearance than that of a siliceous paste of considerable purity.

The same effects appear to take place with regard to rock crystals, as with the calcareous spars. They are formed whenever their principles, in a state of extreme division and attenuation, are suspended by water, and deposited with all the circumstances which nature requires in order that crystallization may take place. I do not even think it necessary to recur to the property which water possesses of sensibly dissolving silex, to explain the formation of these crystals: and we shall refer the formation of quartzose stalactites, agates, &c. to the same cause.

Rock crystal is frequently coloured by iron, in which case it assumes peculiar shades, which have been denoted under different names. We shall place them here as simple varieties.*

VARIETY I.

Red Crystal—False Ruby.

It is frequently mixed with different shades. Its colour is destroyed by fire, according to Mr. D'Arcet. It is found in Barbary, in Silesia, in Bohemia, &c.

When it is of a dull red, it is called the Hyacinth of Compostella.

* Very handsome rock crystals are found in the States of Pennsylvania, Maryland, Virginia, Kentucky, South-Carolina, and New-Hampshire.—*Am. Ed.*

VARIETY II.

Yellow Crystal—Bohemian Topaz.

It has sometimes a tinge inclining to yellow; its colour is often internal only. It is found in Velay, near Bristol in England, &c.

VARIETY III.

Brown Crystal—Smoky Topaz.

This brown tinge varies from a light brown to a deep black. It is affirmed that they may be rendered clear by boiling them in tallow.—See *Journal de Physique*, t. vii. p. 360.

It is found in Switzerland, in Bohemia, in Dauphiny, &c.

VARIETY IV.

Green Crystal—False Emerald.

This is the most scarce and the most precious of coloured crystals. It is found in Saxony and Dauphiny.

VARIETY V.

Blue Crystal—Water Sapphire.

It does not appear to differ from the true sapphire, excepting in being less hard. I have seen a specimen which had this colour. It is found in Bohemia, in Silesia, and at Puy in Valay, which has caused it to be called the Sapphire of Puy.

VARIETY VI.

Violet Crystal—the Amethyst.

Its colour is more or less deep ; and it assumes a considerable brilliancy by polishing. When the crystal is only half coloured, it is called *Prime d'Amethyste*. It loses its colour by a strong fire, according to Mr. D'Arcet. This crystal is found of sufficient magnitude to form columns of more than one foot in height, and several inches in diameter.

DIVISION II.

Quartz.

Those specimens of siliceous stone in which no regular form appears, and which we here comprehend under the name of Quartz, possess various degrees of transparency.

Its colour differs prodigiously ; and it may be distinguished into varieties and shades perhaps more numerous than in rock crystal itself.

It seldom forms entire mountains, but almost always intersects, by veins more or less wide, the mountains of primitive schistus. At all events, I have made this observation in every mountain of this kind which I have examined.

The blocks of quartz, detached by waters, are rolled, rounded, and deposited in the form of large stones on the banks of rivers. The same stones, more attenuated, form the quartzose pebbles ; and these, still more divided, produce sand.

This stone is very refractory. It is used as the basis of bricks employed in the construction of glass furnaces. For this purpose it is calcined to whiteness, and in that state thrown into water. By this means it may be easily reduced to powder, and disposed to form a combination with clay.

Quartz, well pounded, and used in the composition of bricks, does not equally resist the impression of fire, if the precaution of calcining it, and extinguishing it in water, has not been taken. I have obtained a proof of this fact, by employing the same kind of quartz in both ways.

This sand forms an excellent mortar with good lime ; and, when fused with alkalis, it produces a very beautiful glass.

SPECIES III.

Silex, Alumine, Lime, and Iron, intimately mixed.

The state of fineness in the constituent principles, and their more or less intimate mixture or amalgamation, appear to us to establish two divisions among the stones of this species. We shall accordingly distinguish them into coarser flints and finer flints. The first form gun flints, petrosilex, &c.; the second comprehend agates, calcédonies, &c.

DIVISION I.

The Coarser Flints.

In this place we shall arrange two stones which appear to differ only by a more or less evident degree of transparency. The silex, or flint properly so called, is semi-transparent, when very thin, as for example at its edges : the petrosilex has a more opaque colour.

1. Gun Flint.—The gun flint gives fire with steel : its colour is usually brown ; and its surface very frequently exhibits a whiter colour than the middle, and less hard than the nucleus of the stone. This external part sticks to the tongue, and indicates a commencement of decomposition.

The abbé Bacheley has asserted that marine productions, such as polipiers, shells, &c. are capable of passing to the state of gun flint.—*Journal de Physique, Supplement, 1782, t. xxv.*

The specific gravity of gun flint is from 2.65 to 2.7. This stone does not melt in the fire; but it becomes white and brittle by repeated calcinations.

The common brown silex afforded by analysis to Mr. Wiegleb, per quintal, eighty silex, eighteen alumine, and two iron.

2. Petrosilex.—The colour of petrosilex is a deep blue, or a yellowish grey. It is interspersed in veins through rocks; and from this circumstance it derives its name.

Its specific gravity is from 2.59 to 2.7.

It becomes white in the fire like gun flint; but it is more fusible, for it flows without addition. Soda does not totally dissolve it in the dry way; but the borate of soda, and the phosphates of urine, dissolve it without effervescence.

Mr. Kirwan obtained from a petrosilex, used in the manufacture of porcelain by Mr. Lauraguais, seventy-two parts silex, twenty-two alumine, and six lime, in the quintal.*

DIVISION II.

The Finer Flints.

This division exhibits several stones, which, though distinguished by names and a different value, are nevertheless only varieties of each other. We shall content ourselves with enumerating the chief.

1. Agate.—This is a semi-transparent silex of a very fine body. Its texture is vitreous; and its hardness such that it resists the file, gives fire with the steel, and takes the most beautiful polish.

The agate when exposed to the fire, loses its colour, becomes opaque, and does not melt.

The varieties of agates are infinite. They are founded on the colour; and they are distinguished into clouded, punctuated, spotted, irised, herborized, mossy, &c. See Daubenton.—The name of Onyx is given to that

* Flint stones have been found in Pennsylvania, New-York, and Virginia.—*Am. Ed.*

kind of agate which is formed by concentric bands. Mr. Daubenton has proved that the agate which has received the name of mossy, is really coloured by small mossy vegetations.

The purest agate is white, transparent, and nebulous. Such is the oriental agate, which besides appears as if it had protuberances or knobs on its surfaces.

Its specific gravity is 2.64. I consider the agates, and the other flints concerning which we shall proceed to treat, as quartzose stalactites. The sides of geodes which are agatized, and the strata of those flints which are found in places where infiltrations produce rock crystals, appear to me conclusive in favour of this doctrine. The agates have the same relation to quartz as the alabasters to calcareous stones, and the theory of their formation is the same. Mr. Dorthes has exhibited many proofs of this theory respecting the formation of these stones.*

2. The Opal.—The semi-transparent agate of a milky whiteness, which exhibits a glittering, changeable, internal colour of a blue, red, and green tinge, is known by the name of Opal. That which comes from Hungary has a kind of greyish clay for its gangue. The most beautiful opal is the oriental opal; sometimes called the spangled opal, because its colours appear like equal spots distributed over its whole surface. These opals have received various names, according to the colours they reflect.

The chatoyant stones, or such as vary their colour according to the position of the light, and the eye of the observer, are varieties of the opal. Such are the girasol, the cat's eye, the fish's eye.

The reflected rays of the girasol are weak, blueish, and mixed with an orange yellow. This stone has been found in the lead mines of Chatelaudren in Brittany. The most obvious character of the girasol is, that it exhibits in its internal part a luminous point; and reflects the rays of light in whatever position it may be turned, when it is cut into a globe or hemisphere. The cat's eye has a point near the middle, from which proceed, in a circle, greenish

* The agate has been found in Virginia.—*Am. Ed.*

traces of a very lively colour. The most beautiful stones of this kind are of a grey and mortdoré colour. They come from Egypt and Arabia.

The fish's eye does not differ from the cat's eye excepting in its colour, which is blueish: it is found at Java.

3. Calcedony.—The calcedony is a semi-transparent agate of a milky whiteness, differing from the foregoing in not possessing the chatoyant property, or changeableness of colour.

It has been found in the mines of Cornwall, in stalactites of singular elegance. These calcedonies are almost always covered with protuberances like the stalagmites.

The protuberances appear to be formed by the successive apposition of several strata or coatings.

In Monte Berico, in the territory of Vicenza, geodes of calcedony are found which inclose water. They are called Enhydria.

I possess, in the Mineralogical Cabinet of the province, calcedonies of Auvergne, which appear to be crystallized like rock-crystal. The crystals have all the fat and unctuous appearance of the same balls which are dispersed on the rock; but, when they are broke, it is seen that the appearance arose from a covering of calcedony over the crystal of quartz.

Mr. Bindheim analyzed calcedony, and found, in the centenary, 83.3 silex, 11 lime, 1.6 alumine, and a small quantity of iron.—Schrist. Natur. For. Free. t. iii. p. 429.

Mr. Darcet did not succeed in fusing calcedony, but it lost its colour.

Calcedony has often a shade of blue, yellow, or red.

Mr. De Carozy and Mr. Macquart observed in Poland the transformation of gypsum to the state of calcedony.—See the Essai de Minéralogie par M. Macquart, premier mémoire.

Cacholong. The white and opaque calcedony is known by the name of Cacholong. Its texture resembles that of quartz, and it becomes white in the fire. This stone is capable of a fine polish. It is found on the banks of a river named Cach, near the Kalmouks of Bucharina, in whose language the word *cholong* signifies stone.

An imaginary value has been given to a modification of the cacholong, which has the property of becoming transparent after having been plunged in water. This is called Hydrophanes, Lapis Mutabilis, Oculus Mundi. Mr. Dantz brought hydrophanes to Paris, which became transparent when plunged in water.

Mr. Gerhard, on the 28th of August, 1777, read to the Academy of Berlin Observations on the Hydrophanes. He found that this stone contained two-thirds of clay, and one third of silex. This celebrated naturalist affirms that the hydrophanes was known to Boyle, who saw one of them about the size of a pea sold in London for two hundred pounds sterling.

The hydrophanes is fusible in the fire. Soda dissolves it with effervescence; the borate of soda, and the phosphates of urine, without effervescence.

5. Carnelian. Sardonyx. The carnelian is a species of agate, nearly transparent. It is called Carneole when it has the colour of flesh. Its hardness varies prodigiously. Those which are white or yellowish are not sufficiently hard to give fire with the steel. When ignited it loses its colour, and becomes opaque. The most beautiful specimens resemble the garnet. Its specific gravity is from 2.6 to 2.7.

The sardonyx is a semi-transparent silex, of an orange colour, more or less deep. It is knobbed like the calcedony; and possesses the hardness and specific gravity of that stone. Its habitude in the fire resembles that of the agate. In the Royal Wardrobe of France there are vessels of sardonyx of an astonishing magnitude and beauty. The famous murrhine vases were of sardonyx. Sage, t. ii. p. 163.

SPECIES IV.

Silex, Alumine, and Iron.

Jasper is one of the hardest stones we are acquainted with. It is susceptible of the finest polish; and its colour varies prodigiously, which has occasioned it to re-

ceive the names of Sanguine Jasper, Green Jasper, Flowered Jasper, &c.

Mr. Wedgwood assured Mr. Kirwan that jasper hardens in the fire without melting; and Mr. Lavoisier could not obtain a perfect fusion by the assistance of oxygenous gas. The surface only becomes vitreous.

Mr. Gerhard asserts that some species are fusible; and Mr. Kirwan attributes this property to the mixture of lime and iron which produces the fusion.

Its excessive hardness has induced the savages of Canada to avail themselves of it in the fabrication of the heads of javelins.

Mr. Dorthes has found, among the worn stones of the Mediterranean shore, javelin-heads of porphyry, jasper, horn-stone, schorl, variolite, &c. probably fabricated by the ancient inhabitants, the Gauls.

These javelin heads are commonly known by the name of Thunder-stones, and are distinguished by lithologists by the name of Ceraunites.

SPECIES V.

Silex, Alumine, Lime with a small portion of Magnesia, and Iron.

This species comprehends all the schorls; and most of the volcanic products. As the tourmaline is evidently nothing more than a variety of the schorl, we shall place it here, though analysis has not discovered an atom of magnesia in it, and the nature of its principles confounds it with precious stones. Moreover by placing it between these and the schorls, it possesses a situation assigned to it as well by its natural characters as by its constituent principles.

I. The Tourmaline.—This stone possesses the transparency of the schorl. Its appearance and fracture are vitreous, its texture lamellated, its hardness so considerable as to cut glass. When heated to the two-hundredth degree of Fahrenheit, it becomes electrical; a stronger fire deprives it of this property. It is fusible by the blow.

pipe, with ebullition: the pure tourmaline was melted into a black glass, in the experiments of Mr. Lavoisier.

Tourmalines have been found in the island of Ceylon, in Tyrol, and in Spain.

Its form is that of a nine-sided prism, terminated by two flat trihedral pyramids. Mr. De Joubert possesses one whose prism is seven inches and a half long, and eleven inches in circumference.

The prismatic tourmaline has no electric effect but according to the direction of its column; the sphere of activity of the Spanish tourmaline is less extensive than that of Tyrol.

The valuable researches of Bergmann upon this stone may be consulted in his dissertation concerning its analysis. Mr. Tofani has annexed a set of interesting notes to his translation of this work.

The results of Bergmann's analysis exhibit its component parts in the following proportion:

1. The tourmaline of Tyrol contains alumine forty-two, silice forty, lime twelve, iron six.
2. The tourmaline of Ceylon, alumine thirty-nine, silice thirty-seven, lime fifteen, iron nine.
3. The tourmaline of Brazil, alumine fifty, silice thirty-four, lime eleven, iron five.

The specific gravity of the tourmaline of Ceylon is 30,541, that of Spain and of Tyrol is 30,863, water being 10,000.—See Brisson.

II. Schorl. The distinct properties of schorl are, an appearance of semi-vitrification, fusibility in a moderate fire, and hardness approaching to that of crystal.

There are few stones which exhibit a greater variety of form or colour.

They enter into the composition of porphyry, of serpentine, of granite, and are very frequently found with the magnesian stones.

We shall distinguish the schorls into crystallized and irregularly-shaped schorls.

A. All the varieties which depend upon colour may be reduced to four.

1. Black Schorl.—The black schorl is found chiefly in granites.* It has almost always the form of prisms more or less perfect. The number of sides of these prisms is various: they are sometimes grooved; they sometimes terminate in trihedral obtuse pyramids, placed in contrary directions; in some places they are found several inches long, and the union of these prisms frequently forms groups of several in diameter. Their black colour is more or less deep. When urged by fire, they become resolved into a black uniform glass of an imperfect fluidity like paste.

The analysis of the black prismatic schorls of Gevaudan afforded me, per quintal, fifty-two silex, thirty-seven alumine, five lime, three magnesia, and three iron.

2. Green Schorl.—This variety exhibits the same form, and the same modifications; but the most common of its crystallizations is that of a tetrahedral prism, terminating in short pyramids likewise tetrahedral.

3. Violet Schorl.—This variety was discovered in 1781 by Mr. Schreiber, below the grotto of Aunis; situated at the distance of one league from Bourg D'oisan in Dauphiny. Mr. De la Peyrouse likewise found it at the Peak of Dretliz, in the Pyrenean Mountains.

This Schorl possesses a certain degree of transparency. It is crystallized in rhomboides; its texture is lamellated; two of the rhomboidal planes of each pyramid have their faces striated parallel to each other.

Schorl loses its colour in the fire, and one thirteenth of its weight; it becomes of a greyish white: and with a stronger degree of heat it swells up, subsides, and forms a black enamel.

Its specific gravity is 32,956, according to Brisson.

4. White Schorl.—This variety has been found in the mountains of Corsica, Dauphiny, and the Pyrenees. It is of an opaque white colour, and vitreous appearance; and is found in crystals on the surface of certain stones of the nature of the lapis ollaris. I have seen a layer of this schorl between amianthus and the lapis ollaris. It melts in the fire into a white enamel.

* Crystallized black schorl is found in the granite of the United States.—*Am. Ed.*

The analysis of this schorl from the Pyrenean Mountains afforded me, per quintal, fifty-five parts silex, twenty-two alumine, thirteen magnesia, and seven lime.

B. The schorl in connected masses nearly approaches the jasper in its external characters. It may be distinguished however by its fracture, which is of a dryer grain, and exhibits a disposition to crystallization. This stone serves as the basis to several porphyries. The variolite of Durance, a stone singular on account of the superstitions to which it has given rise, is a schorl in the mass, covered with grains of the same nature as the ground, but of a clearer green.

Mr. Dorthes has observed variolites on the coast of our Mediterranean sea; and affirms that this stone in its decomposition undergoes changes of colour which succeed each other in the order of the solar spectrum.

III. Volcanic Products.—The principal products of volcanos are basaltes, lava, and terra pozzolana. These substances are absolutely of the same nature; but they are principally distinguished by the name of Basaltes when their form is regular. When they have no determinate figure, they are denominated Lavas; and when considerably attenuated they are distinguished by the name of Terra Pozzolana.

Basaltes is distinguished into the prismatic basaltes with a number of sides, from three to seven; the basaltes in tables and the spherical basaltes.

Lava is distinguished into compact lava, porous lava, twisted lava, lava in tears, &c.

Several naturalists have classed the basaltes with the schorls, and some of them have assigned the same origin to both. It appears nevertheless to be generally agreed that basaltes is a product of fire.

It sometimes differs from schorls in its chemical analysis, and also in the circumstance of its not always affording magnesian earth.

The colour of basaltes is of a deep green, almost constantly covered or enveloped with a ferruginous crust less black than the internal part. The iron is in the state of ochre.

Its form is constantly prismatic, which is the natural effect of the contraction which it suffers in cooling.

Basaltes is converted by fire into a most beautiful black glass. This property, which is admitted by every chemist, induced me to fuse it, and blow it into bottles.

The attempt was perfectly successful at the glass-house of Mr. Gilley of Allais, and at that of Mr. Giral of Erepian. I still preserve the first vessels which were blown of this substance: they are of the most beautiful black, astonishingly light, but without transparency. Encouraged by this first success, I requested Mr. Castelveil, the proprietor of another glass-house, to undertake some experiments; and in consequence of various trials we succeeded in fabricating bottles of an olive green, in which the most extreme lightness, and a truly astonishing degree of solidity, were united. Pounded basaltes, soda, and sand, in nearly equal proportions, formed their composition. The properties of these bottles, as proved by my own experiments, as well as by those which Mr. Joly de Fleury, at that time comptroller-general, ordered to be made, render them of the greatest value in commerce; and Mr. Castelveil was unable to supply the numerous orders he received. This manufacture supported itself with success for two years: but at the end of that time the superiority of the bottles ceased to be the same; the manufacturer received the reproaches of the consumer; this superb establishment gradually fell off, and was at length abandoned.

Since that period I have made several experiments in the large way, from which I have obtained results that may be of service to such as are desirous of following this manufacture.

1. The nature of the combustible used in glass-houses has a prodigious effect in modifying the results of experiments. The same basaltes which Mr. Castelveil considered as too refractory in his furnace heated by wood, was found of too fusible a nature by Mr. Giral, who was in the habit of using pit-coal in his glass works. The former manufacturer accordingly made his glass by adding soda to the lava, whilst the latter mixed it with a very refractory sand.

2. The same lava, fused without addition, may be blown in one glass-house, and not in another. This irregularity appeared to me at first to depend essentially on the skill of the workmen; but I have been since convinced that it is totally independent of that circumstance.

In a furnace which is strongly heated, the fused lava sometimes becomes fluid like water, and drops from the iron tube as soon as it is collected. The same lava, when fused in other furnaces will preserve a sufficient degree of consistence to admit of being blown. I am myself well assured that the lava might be wrought in any glass-house whatever, provided the moment was seized in which the paste was neither too fluid nor too thick to be wrought; but these attentions are too delicate, and too minute, to be observed in works in the large way.

3. The hardest basaltes affords the most beautiful glass. When it is contaminated with foreign principles, such as the nodules of lime, the glass is brittle, and has not a sufficient connexion of its parts. This circumstance, in my opinion, was the cause of the bad quality of the glass, which produced the failure in Mr. Castelveil's manufactory.

4. I have seen very hard basaltes interspersed with black infusible points, insomuch that these points became enveloped in the vitreous paste without any perceptible alteration. The volcanic mountain of Escandorgue near Lodeve afforded me this variety of basaltes.

In the article Verrerie of the *Encyclopédie Methodique*, may be seen the various results which we have obtained with Mr. Allut, in several experiments made in common in the royal glass works of Bosquet and elsewhere.

I shall conclude, from the observation which my experiments have hitherto afforded—

1. That lava may be used as a flux in glass-houses to diminish the consumption of soda. This is the single purpose I at that time proposed to myself, and I have clearly accomplished it. 1. By the results of experiments which have shewn that refractory sand becomes fused in the glass furnace by a mixture of lava. 2. By the effects obtained in all the works in the large way, in which the addition of lava permitted a diminution in the proportion of soda.

2. It is very difficult to establish a rigorous process, applicable to all circumstances, by which lava may be wrought without addition. My bottles into which the lava entered as a component part, were scarcely known, before it was published that they were formed of lava without addition; nothing more being said to be required than to fuse the lava in order to form bottles. This strange report affected me very little in the principle; because I had neither spoken, written nor printed any thing which was capable of giving authority to such an error: and I was content to reply to all persons who demanded information, by informing them that experience had taught me that an addition of lava diminished the proportion of soda in the composition of glass, and that this new principle rendered the bottles lighter and stronger.

3. That the only advantage which can be derived from fusing lava without addition, is to pour it out into moulds, to form paving stones, chimney jambs, &c. The facility with which it is fused by the assistance of pit-coal, would render these works of small expense; and it might easily be decorated by incrusting it with metallic colours.

4. That the difference in the nature of volcanic products produces such a variety in the results of their fusion, that I consider it as impossible to assign a constant and invariable process, by which the same result may infallibly be obtained. This circumstance renders it necessary to make preliminary trials in all cases wherein it is intended to use basaltes in the fabrication of bottles.

The basaltes has been considered as similar to a stone known by the name of Trapp: it resembles it in several essential properties: the colour, form, weight, and the nature of the component parts of each, appear to authorize us in confounding them together, as Bergmann has proved by the fine comparison he has made of these two stones, in his analysis of the volcanic products of Iceland. But this same chemist has shewn that they differ in several other points of view.

The trapp exhibits no character which can give ground to suspect that its origin is volcanic; it is found in Sweden, in the primitive mountains, and upon strata of granite and schistus, and sometimes even upon banks of calcareous stone.

The trapp of the mountains of Westrogothland is usually in the form of square irregular cubes; and it is indebted for its denomination to this resemblance to the steps of a stair case. It likewise exhibits the form of a triangular prism, though seldom; and sometimes it resembles immense columns.

The trapp afforded Bergmann the same principles, and nearly in the same proportion, as the basaltes. The difference is scarcely the hundredth part; and this variation is frequently found in pieces of the same basaltes.*

* Basaltic stones are found at Flour-town, about thirteen miles from Philadelphia; and on the Conewago hills east of the Susquehanna, and half a mile east of Elizabeth-town. At this place they are interspersed with large masses of brechia, composed of pebbles rounded by friction, imbedded in the red free stone of the mountains.

The following is an account of a basaltic wall, discovered under the surface of the earth, in North-Carolina, in a letter from the Rev. James Hall, A. M. to the editor of this work, with his reply.

Near the confluence of South Yadkin and Third Creek, about fourteen miles from Salisbury, in North-Carolina, a phenomenon of great antiquity has been discovered, which has engaged the attention of the curious in that part of the state, and which I have lately endeavoured to explore.

During the heavy rains which fell in the summer of 1794, a cavern of about eight feet deep was formed in the side of a hill, near a small stream of water, by the successive torrents of rain-water which issued from an adjacent field.

The hill is between two and three poles in surface where the cavern is formed, about the middle of which stands a subterranean wall, composed of small stones, laid in a white cement, resembling lime of a very fine texture. The largest stones, among many hundreds which I have examined, do not, in my opinion, exceed twelve pounds in weight, and from that are to be found of all sizes down to the weight of one ounce.

The species of stone is what the Irish call the *black whin*; nor is any other kind of stone to be found in the wall.

The stones incline to an oblong, though they are very irregular in their form.

They are universally laid across the wall; and the angles of each stone are so fitted by those contiguous to it, that it is difficult to enter the edge of a mattock between them, although the cement has lost its tenacious quality, and is as moist as the surrounding earth.

The cement I have examined in not less than forty different places in the wall, and could not find among it any appearance of sand or common earth, except where there has been an opportunity of the earth mingling with it from the top of the wall.

SPECIES VI.

Silex, Lime, Magnesia, Iron, Copper, and the Fluoric Acid.

This combination forms the chrysoprase. Its colour is a semi-transparent apple green, and it is harder than the fusibles spars and quartz of the same colour.

Both sides of the wall are plastered with the cement, so that not a stone has appeared when the wall was completed, supposing it to be a work of art; and that this is the case is, in my opinion, evident from this circumstance; that where the cement was washed off from the surface of the wall, hundreds of small stones appeared within a small space, as if slipped in between the ends of the stones, where they could not be brought into contact, to fill up the chasms with the cement about them; and from the apparent nature and situation of the materials, it appears probable to me, that when the wall was dry, and above ground, it was nearly as firm as a solid rock of the same dimensions.

The wall is about two feet thick, built in a straight line, and perpendicular. It has been traced about ninety feet down the stream below the cavern, and, perhaps, double that distance in the opposite direction. That part I did not measure.

The top of the wall, at an average, is between two and three feet below the surface of the earth, both above and below the cavern, although the situation of the ground on the two sides is very different.

Above the cavern the hill rises abruptly, where the wall rises with it, and, in a few poles, the ground becomes almost level, the stream bearing considerably from the wall.

Below the cavern the wall runs parallel to, and along the declivity of the hill; so that, as far as the wall has been explored, the end which is up the stream is, by a horizontal level, fifteen, perhaps twenty, feet higher than the other.

Where the wall bends over the hill the stones lie in a much more detached situation than in any other place which I examined, and appear as if the lower end had sunk when the cement was in a state of moisture, so as to admit the stones to be drawn asunder, rather than make any particular chasm.

Two circumstances have much excited my curiosity respecting the wall; one is, that it has been explored five feet lower than the surface of the adjacent stream, which runs not more than forty feet distant from the wall, without any appearance of its termination downwards, or of any end, corner or opening discovered in the distance of near three hundred feet in length where it has been traced. The other is, that a coarse gravelly rock embraces the wall on both

The fire deprives it of its green colour, renders it white and opaque, and forms by the assistance of vital air a compact and milky globule.—See Ehrmann.

sides, increasing in hardness as far as the wall has been examined in depth; from which I think these two facts are evident, that, at the time the wall was built, the adjacent stream had no existence in that place; and that, since that time, the rock has been generated.

The wall has had so little tendency to form a concretion with the rock, that, as far downwards as the rock would yield to the mattock where it was dug away, the plastering stood smooth and entire; and, where the rock is too hard to be dug, and the wall was removed, the cheeks of the rock which embrace the wall are as level and smooth as the plastering against which it rested. This, I think, incontestibly proves, that the rock has been formed after the wall was constructed.

The depth at which the wall has been examined is supposed to be about fourteen feet. This I could not exactly ascertain, as the wall had been demolished for near sixty feet in length.

It is my intention, if health permit, next August, to endeavour to carry forward a further inquiry, the result of which you may expect by the first convenient opportunity.

Editor's Reply.

Sir,

I have read your account of a supposed artificial wall, discovered under the surface of the earth, in North-Carolina, with great attention.

I am well satisfied, from several specimens of the stones which I have seen composing this wall, that it consists of a mineral substance called basaltes, and that it is a production of nature, and not of art.

My reasons for this opinion are as follow:

The stones answer the description of basaltes given by various writers. They are found of an irregular form, in prisms consisting of several sides, and are of different sizes; some being so small as to weigh no more than one ounce, while others exceed the weight of twelve pounds. The angles fit each other exactly like the basaltes, and appear as if joined by the hand of a skilful workman.

There is a brown ochreous matter found upon the surfaces of these stones, exactly like that on some of the basaltes of other countries. This ochre arises from a chemical decomposition of the stone, called by some spontaneous calcination, and by others efflorescence.

Mr. Achard obtained, in the quintal of this stone, 95 parts silex, 1.7 lime, 1.2 magnesia, 0.6 copper.

The decomposition is owing to the iron contained in the stones, and its calcination by air and water.*

Fourcroy has improperly attributed the brown crust with which the stones are covered, to water depositing different kinds of earth between the sides of the basaltic columns; and in Nicholson's Chemical Dictionary † it is called cement with equal impropriety. Columns of the Giant's Causeway, says the compiler of the Dictionary, fit accurately together, being, in some instances, united by a strong cement.

That the brown crust which adheres to the stones, and the fine white friable matter with which you suppose the wall has been plastered, are owing to chemical decomposition, appears evident from the following circumstances: If the brown ochre is carefully scraped off from the stone, the surface will be found to be not of so firm a texture as the internal part; and the white powder, brown crust, and internal part of the stone, are composed of the same principles, in nearly the same proportions.

In some countries the basaltes are so much calcined as to fall to pieces on being removed.‡

The regularity of the wall, and the number of small stones which appear as if slipped in between the ends of the stones, are no proofs of its being a production of art. The basaltes, in Italy, appear like piles of wood of equal thickness throughout, and extend to a considerable distance.

Faujas Saint Fond informs us that in Scotland there is a vast basaltic wall perfectly straight and upright, eighty-nine feet long and twenty-five feet high. Travels, vol. ii. p. 127.

The following account of the cave of Fingal, extracted from Garnet's tour through Scotland, will shew how little the regularity of the wall contributes to prove, that it is an artificial production.

"As we turned the southern point of the island of Staffa, the basaltic columns became vastly more regular, and the view on this side of the island was grand beyond conception: it appeared like the end of an immense cathedral, whose massy roof was supported by stupendous pillars, formed with all the regularity of art.

Proceeding still further along the same side of the island, we had a view of Fingal's cave, one of the most magnificent sights the eye ever beheld. It appears like the inside of a cathedral, of immense size, but superior to any work of art, in grandeur and sublimity, and equal to any in regularity.

Regularity is the only part in which art pretends to excel nature, but here nature has shewn, that when she pleases she can set man

* Il est facile de voir que cette decomposition, cette friabilité dependent du fer qui est contenu dans ces pierres, et de son oxidation par l'air et par l'eau. French Encyclopædia, art. basaltes.

† Art. basaltes.

‡ Histoire Naturelle de la France Meridionale, tom. ii, p. 52. par M. l'Abbe Giraud Soularie.

SPECIES VII.

Silex, the blue Fluete of Lime, with the Sulphate of Lime and Iron.

This singular combination forms the Lapis Lazuli, or Azure Stone.

at nought, and make him sensible of his own littleness. Her works are in general distinguished by a grand sublimity, in which she disdains the similar position of parts, called by mankind regularity, but which, in fact, may be another name, for narrowness of conception and poverty of idea; but here in a playful mood, she has produced a regular piece of workmanship, and on a scale so immense, as to make all the temples built by the hand of man hide their diminished heads."

Dr. Vantroil speaking on the same subject says—"This piece of nature's architecture surpasses every thing that invention, luxury or taste, ever produced among the Greeks."

The small stones may have been carried down from the surface of the earth by rain, and deposited in the places where they are now found.

I do not suppose that the rock which embraces the wall, and which, from the specimen you have shewn me, is granite, was formed after the wall, granite being among the first formed substances in nature. The rock has probably been burst asunder by the wall, which is, perhaps, of volcanic origin.

In Cronstedt's Mineralogy there is an account, by Mr. Latrobe, of a rock of granite in Upper Lusatia, which has been rent asunder by a vein of concentric basaltes. In Italy basaltes are often found resting upon a bed of granite.

That there have been volcanos in North-Carolina appears from some specimens of lava sent from that part to this city.

The following experiments were made in order to ascertain the component parts of the American basaltes:

EXPERIMENT I.

One hundred grains of the solid stone were reduced into an impalpable powder, and boiled half an hour in half an ounce of nitric acid, diluted with one ounce of water. The whole was placed upon a filter, and distilled water was added until it passed through the filter, insipid to the taste. The powder remaining upon the filter was siliceous earth, and, when dry, weighed exactly fifty-eight grains.

EXPERIMENT II.

A solution of potash was added to the fluid which passed through the filter until no precipitation took place. The precipitated matter was carefully washed in a large quantity of distilled water, and, when dried, weighed forty grains.

Its colour is of a beautiful opaque blue, which it preserves in a strong heat, and does not suffer any alteration in this respect by the contact of air.

EXPERIMENT III.

This dried precipitate was boiled half an hour in distilled vinegar, in order to dissolve the lime and magnesia which it might contain. The vinegar was filtered and evaporated to dryness. Diluted sulphuric acid was added to the dry matter, in order to form selenite, or the sulphate of lime, and Epsom salt, or the sulphate of magnesia. Distilled water was added to separate the sulphate of magnesia from the insoluble sulphate of lime.

The magnesia was precipitated by a solution of potash, and, when dried, weighed three grains.

EXPERIMENT IV.

That part of the dried precipitate, mentioned in the second experiment, which was not acted upon by the vinegar, weighed twenty-nine grains. It was dissolved in diluted nitric acid, and a solution of the prussiate of potash was added until no precipitation took place. The prussiate of iron was separated by a filter, boiled in a solution of potash, washed well with distilled water, and dried, when it weighed ten grains.

EXPERIMENT V.

A solution of potash was added to the filtered liquor of the last experiment, until no precipitation took place. The precipitate, which was alumine, was well washed in distilled water, and, when dry, weighed sixteen grains.

The proportions of the ingredients composing the American basalt, from these experiments, are fifty-eight parts of siliceous earth, sixteen of argillaceous, three of magnesia, and ten of iron, which, added together, make eighty-seven. Counting two grains lost in the first experiment, and five in the other, we will have ninety-four grains, which, with six allowed for the lime, will make one hundred grains.

One hundred grains of the white friable matter called cement, and the same quantity of the ochreous crust, were subjected to the same kind of experiments, and gave the following result :

Silex. Alumine. Lime. Mag. Iron. Loss.

White friable powder,	55	16	5	3	12	9
Brown ochreous crust,	54	15	6	3	11	11
Powdered stone,	58	16	6	3	10	7

Upon comparing this analysis with those of Bergmann, Mongez, and Faujas de Saint Fond, no great difference will be found in the proportion of the ingredients composing the American basalt and those of other countries.

The powder of this stone makes a slight effervescence with acids; but after calcination it forms a jelly with acids, without exhibiting any previous effervescence.

The powder of this stone forms the valuable colour known by the name of Ultramarine. The price of this colour is proportioned to its intensity; and its value is accordingly least when it is mixed with pyrites, because these bodies diminish the vivacity of its colour.

This stone affords water by calcination, and when distilled with the muriate of ammoniac, it forms martial flowers; which proves, according to Mr. Sage, that its colour is owing to iron.

The azure stone is fused by a strong heat into a whitish glass; and by the assistance of oxigene it forms a white transparent globule inclining to green, without internal bubbles, and not obedient to the magnet.

The specific gravity of the lapis lazuli of Siberia is 29,454.—See Brisson.

Plates of the lapis lazuli may be seen upon almost all richly decorated altars; it is likewise made into toys.

Margraff obtained from this stone calcareous earth, gypsum, iron, and silex. Mr. Rinnmann has discovered that it contains the fluoric acid.

SPECIES VIII.

Silex, Alumine, Barytes, and Magnesia.

This stone is known by the names of Feld Spar, Rhomboidal Quartz, Spathum scintillans, Petuntze.

It very frequently forms one of the principles of granite, and the crystals, which are found separate, arise from the decomposition of this primitive rock.

Analysis by Bergmann, Mongez, Faujas de Saint Fond:

Silex,	52	56	46
Argillaceous earth,	15	15	30
Lime,	8	4	10
Iron,	25	25	8
Magnesia,	0	0	6

100	100	100
-----	-----	-----

Q q

The texture of feld spar is close, lamellated, and it is less hard than quartz.

It fuses without addition into a whitish glass. I have nevertheless observed a very great variety in the feld spars, with regard to their habitude in the fire. That of A-venne, which is in the form of whitish crystals mixed with quartz, afforded me a transparent glass of extreme hardness by the simple addition of one-third of lime : whereas that of Esperon, treated in the same manner, did not exhibit the smallest sign of fusion.

The specific gravity of white feld spar is 25,9'5.— See Brisson.

Feld spar exhibits several varieties in its form and colour.

Most of the pieces of feld spar inclosed in granite have a rhomboidal form ; and when this primitive rock becomes decomposed, the crystals of feld spar are detached, and remain confounded with the rubbish. The granites of our province, almost all of them, contain these crystals, some of which are an inch and a half in diameter.

Feld spar has been found crystallized in tetrahedral prisms, terminating in pyramids with four sides.

I possess some specimens of feld spar of Auvergne, whose tetrahedral prisms are flattened and terminated by a dihedral summit.

The principal shades of colour in feld spar are white, rose-colour, and chatoyant, or of changeable colours.

The white transparent feld spar is very rare ; there is a piece in the Royal Cabinet of the mineral School, which comes from Mount St. Gothar.

One hundred parts of white feld spar contain about sixty-seven silex, fourteen alumine, eleven barytes, and eight magnesia.

The rose-coloured feld spar is not very scarce. Our mountains exhibit much of it. It abounds with iron, which is in the state of ochre. Some experiments have shewn me that this variety is more fusible than the others. My analyses have even exhibited a larger portion of magnesia ; and its consistence appears to me to be less firm than that of other specimens.

Feld spar is composed of rhomboidal lāmīnæ, which give it the property of exhibiting various colours, in a

greater or less degree. Large pieces of feld spar have been found on the northern coast of Labrador, worn down by the waters into a round form, of a blueish grey colour, and exhibiting the most agreeable change of colours, according to the variation of position. The colours are a beautiful celestial blue, shaded with green. This stone is known by the name of Labrador Stone. Granites are frequently found, in which the feld spar exhibits its changeable colours without being wrought.*

CLASS III.

*Concerning the Mixtures of Stones among each other.
Stony Mixtures. Rocks.*

The mixture of the primitive earths with each other form the stones we have hitherto treated of; and these stones, united and connected together, or as it were joined by a cement, constitute the numerous class of pebbles or stones, concerning which we shall proceed to treat. It is evidently seen that the mixture of various stones has been produced, either by revolutions which have reversed and confounded the whole surface of countries, or by the action of waters, which have successively formed the strata of rounded flints spread over the surface of the globe, and have afterwards deposited in their interstices that earthy matter which has connected them together. These mixtures have afterwards acquired a degree of hardness; and at length appeared to form one single substance.

We shall establish our genera upon the presence of such stones as predominate; and the species will be deduced from the variety of stones mixed with that which determines the genus.

* Beautiful red, white, and green feld spar is found accompanying quartz in this country.

A great many varieties of quartz are found in the United States. It composes part of the granites of New-York, and is found of a white and red colour. There is a variety of a dark blue colour, found near West-Chester, Pennsylvania.—*Am. Ed.*

GENUS I.

Rocks formed by the Mixture of Calcareous Stones with other Species.

Though the basis of calcareous stones enters into the composition of the greater part of lithologic substances, we find few rocks which can be ranged in this class.

SPECIES I.

Carbonate of Lime, and Sulphate of Barytes.

Mr. Kirwan observed compound stones in Derbyshire, formed of chalk intermixed with nodules of ponderous spar.

SPECIES II.

Carbonate of Lime and Mica.

The green marble or Cipolin of Autun is of this kind. It is composed of eighty-three parts carbonate of lime, twelve green mica, and one iron.—*Journal de Physique*, t. xii. page 55. Calcareous stones are found in Italy, which exhibit brilliant specks of mica, and are known by the name of Masigno.

SPECIES III.

Mixtures of Calcareous and Magnesian Stones.

Sulphate of lime, fluat of lime, and carbonate of lime, are found mixed with steatites, serpentine, talk, amianthus, and asbestos. Such is, for example, the white marble interspersed with spots of steatites, and described by Cronstadt.

SPECIES IV.

Calcareous Stones, and Fragments of Quartz.

Quartz is sometimes found in calcareous cement. Sweden and Siberia exhibit several marbles which give fire with the steel. The calcareous grit, so common in the southern part of our kingdom, is of this species. The sand is composed of fragments of quartzose flints, rounded and connected by a calcareous gluten or cement. By digestion of grit-stone in an acid, the calcareous cement becomes dissolved, and the proportion which the sand bears to the whole may then be easily determined.

This grit-stone is seldom hard enough to be used in building, or in paving.

At Nemours, and at Fontainebleau, this stone has been found crystallized in perfect rhomboides: the cabinets of naturalists are enriched with superb samples of this kind.

Lime-stone has likewise been found serving as a cement for feld spar, schorl, &c.; but this is somewhat rare.

Mr. De Saussure has described a stone whose elements are quartz and spar.

Our shores afford pebbles of hard marble of a light-grey colour, interspersed with feld spar and quartz.—See Dorthes.

GENUS II.

Compound Stones formed by the Mixture of Barytic Stones with other Stones.

As ponderous spar is of considerable scarcity, and is almost always found alone, this genus will not be numerous.

SPECIES I.

Ponderous Spar mixed with a small quantity of Calcareous Spar.

The diocesses of Alais and of Uzes afforded me this species; and I have myself observed in the latter rhomboids of calcareous spar, so well mixed with the laminæ of ponderous spar, that it is impossible to separate them without destroying the stone. It was among the veins of ponderous spar which are found on the road from Portes to Alais, that I saw this mixture.

SPECIES II.

Ponderous Spar and Serpentine.

Mr. Kirwan describes a species of serpentine with spots of barytes.

SPECIES III.

Ponderous Spar and Fluor Spar.

The ponderous spar of Auvergne is mixed with fluor spar: I have many specimens of this.

SPECIES IV.

Ponderous Spar and Indurated Clay.

This is the Kros-stein of the Germans. The clay which forms the ground is grey, and includes a ponderous spar of a white colour, which is disposed in this clay in the form of veins, that might be taken at first sight for vermiculites, or in general, for the remains of some organized substances. This stone is found at Bochnia in Poland.

SPECIES V.

Ponderous Spar and Quartz.

I have in my collection several specimens, in which the ponderous spar is disposed in stars upon a matrix of the nature of silex.

SPECIES VI.

Ponderous Spar and Lava.

The extinct volcanos of the diocess of Beziers have afforded me lavas, partly decomposed, whose surface exhibits radii of ponderous spar, which, at first sight I took to be zeolite.

GENUS III.

Rocks or Stones formed by the Mixture of Magnesian Stones with other Kinds.

SPECIES I.

Magnesian Stones mixed together.

The same rock often exhibits the various known magnesian stones in contact with each other. Thus we see the asbestos placed beside the amianthus, the serpentine in contact with the asbestos, the steatites in contact with talk.

SPECIES II:

Magnesian Stones and Calcareous Stones.

The serpentine has been found spotted with calcareous spar, and gypsum.

SPECIES III.

Magnesian Stones and Aluminous Stones.

Steatites is frequently mixed with clay. Its fibres are found bedded in an argillaceous substance. Steatites and serpentine are sometimes mixed with schistus.

SPECIES IV.

Magnesian Stones and Siliceous Stones.

Serpentine is found mixed with veins of quartz, feldspar, schorl, &c.

Asbestos and amianthus are often confounded, and sometimes incorporated in quartz and rock-crystal.

Mr. De Saussure has described a compound stone, of which the quartz is white, and the steatites green.

At Sterzing in Tryol, is found a rock formed by schorl and serpentine.

In the county of Mansfield in Saxony, a rock has been discovered, composed of jasper and asbestos.

GENUS IV.

Rocks or Stones formed by the Mixture of Aluminous Stones with other Species.

SPECIES I.

Schistus and Mica.

This mixture forms several primitive mountains. The mica is sometimes in plates of a certain thickness, but most commonly in small fragments; and the stone assumes a brilliant argentine appearance, which renders these stones agreeable to the sight. In this last case, the stone is nearly white, sonorous, and splits into leaves; whereas it is

blackish, and less hard, when the mica is dispersed through it in large grains.

These kinds of micaceous schisti do not become spontaneously decomposed. They differ essentially from the pyritous schistus, whose formation appears to be posterior to that of the present species.

This micaceous schistus is a primitive stone. It does not include minerals, or at least very rarely; and it is not spontaneously decomposed.

SPECIES II.

Schistus and Garnet.

The schistus frequently contains garnets, which rise in protuberances in its texture, and separate its strata from each other. The garnet is crystallized, and one would be disposed to affirm that this stone had increased, and almost vegetated, in the other, which serves as its covering. It is probable that the garnet has been enveloped by this paste of schistus; or that it was formed while the stone was still almost in the fluid state.

I found this schistus filled with garnets in the bed of the river Bramabiou, in the diocese of Alais.

SPECIES III.

Schistus, Mica, and Quartz, mixed in small Fragments.

The Germans call this compound stone by the name of Gneiss. It deserves to be included among the quartzose and siliceous stones; but as it nearly approaches the primitive schisti we have just treated of, we shall follow the natural method in classing it here.

The texture of this stone varies greatly. It sometimes forms a rock in which neither ground nor fibres can be distinguished; in other specimens it appears to be divided into filaments twisted in a thousand manners, and it frequently exhibits a lamellated hard texture.

It is found in large masses of a greyish-green colour, with its surface shining, and polished like the slate; and

it appears to be merely a fine-grained granite, the minuteness of whose parts has suffered them to take the foliated form of the schistus.

Mr. Weigleb has analyzed that of Friburg.

SPECIES IV.

Schistus and Schorl.

The mixture of these two stones is common enough. The schorl is sometimes dispersed in very minute filaments, which give a blackish tinge to the mass. Its form is often prismatic; in which case the fibres of the schistus, and the long crystals of the schorl form the prism by their reunion.

A schistus has been found in the Pyrenean mountains, in which the schorl is spread from space to space in the form of oblong bodies, and equally dispersed over the whole mass.

SPECIES V.

Clay and Quartz.

This constitutes the argillaceous grit-stone, or the stone in which fragments of quartz are united together by an argillaceous gluten.

Several varieties of grit-stone may be distinguished. It is often found in irregular, coarse, and compact masses, which are made into mill-stones, or used for paving, &c.

The magnitude of the fragments of quartz renders the surface more or less rugged; and it is this which renders it proper for certain operations of trituration.

When its grain is finer, it is made into grind-stones. It is by virtue of their quartzous principles that grindstones emit such numerous sparks, when struck with the steel, or when they are moved with rapidity against any tool of that metal.

Argillaceous grit-stone is sometimes of a scaly texture: the Cos Turcica of Wallerius, and the stone used for sharpening scythes, are of this kind.

Fine grit-stone, composed of impalpable particles, is known by the name of Tripoli, from the part of Africa whence it first came. It is now found in Rouergue, in Brittany, Germany, and elsewhere.

The porous grit-stone called Filtering-stone, on account of its use, is of the same nature.

Quartz is sometimes mixed with mica. Our province contains it in various places.

The mica is likewise found mixed,

1. With feld spar, according to Ferber and Kirwan.
2. With schorl, at Mont hykie in Dalecarlia, in Sweden, and at Sterzing in Tyrol.

3. With garnets, at Paternion in Carinthia, and at the Carpathian mountains in Hungary.

4. With garnet and schorl, at Greyner.—See Muller.

5. With quartz, feld spar, and schorl. This composition forms one of the most common granites.

The mixture of these stones, varied in the proportion of their principles or elements, forms the numerous variety of granites: and several colours likewise modify them exceedingly.

GENUS V.

Compound Stones formed by the Mixture and Re-union of Quartzose Stones with each other.

SPECIES I.

Quartz and Schorl.

The quartz is, in general, white in this stone, and the schorl of various colours. Some of the paving-stones of London are of this sort, according to Kirwan. The schorl is likewise found in crystals within the quartz.

SPECIES II.

Quartz and Feld Spar.

A stone of this nature was brought me from the neighbourhood of Avenes. The mountain from which the specimen was detached, contains about one third of quartz. The rest of the rock consists of rhomboidal feld spar, of no great firmness of texture, and constantly exhibiting the rhombus in its fracture.

I possess a very fine specimen of a similar rock, which was sent me from Fahlun in Dalecarlia.

SPECIES III.

Grit-stone and Garnet.

I have received from the mines of Tallard, near Gap in Dauphiny, grit-stones with garnets of one or two lines in diameter interspersed. These garnets are dispersed through the whole mass, at the distance of three or four lines from each other.

SPECIES IV.

Quartz, Feld Spar, and Schorl.

This mixture is common, and forms great part of the granites on our globe.

The proportion of the elements of this rock vary greatly, but the forms of the stones which compose it are not less variable. The schorl is frequently crystallized in prisms; the feld spar almost always exhibits rhomboidal laminæ, on breaking the stone; the quartz very seldom exhibits determinate figures, but it has nevertheless been found in superb crystals at Alençon and elsewhere.

The colour of these stones, likewise, exhibits an infinity of shades. The schorli is usually black; but it is sometimes found green, and even white, as in some granites

brought from Spain. The feld spar is commonly of an ash grey; but it has been observed of a flesh-colour, of a milk-white, of a dull red, &c. The most common appearance of the quartz is, that of a fat and vitreous substance. It is sometimes black.

SPECIES V.

Fragments of Quartz united by a Siliceous Cement.

We may here class the quartzose plum-pudding stones. The cement which unites these pebbles of quartz, which are commonly rounded, is the paste of petro-silex. Some of these pudding-stones are so compact, and their fracture is so uniform, that they are capable of the most beautiful polish, and produce a very happy effect by the variety of colour of the several flints connected by the same gluten.

SPECIES VI.

Jasper and Feld Spar.

This rock is known by the name of Porphyry. The jasper composes the ground, and the feld spar is interspersed in small needles, or in flat parallelopipedons.

The colour of porphyry varies prodigiously. The feld spar, which enters into its composition, is either white, or yellowish, or red; but the name of the porphyry is always dependant on the colour of the jasper. The jasper is sometimes green and sometimes black, and in some instances red; which establishes a great number of varieties.

As this stone is susceptible of the most beautiful polish, it has been employed as an ornament; and our temples, as well as private houses, are decorated with it.

Mr. Ferber found in Tyrol porphyry in prismatic columns, resembling that of basaltes; a circumstance which affords a further degree of probability to the opinion of such as have considered porphyry to be a volcanic production.

Porphyry is found in Egypt, in Italy, in Germany, in Sweden, in France, &c. Mr. Dorthes has brought, from

various mountains in Auvergne, specimens of porphyric basaltes in tables and in masses, containing crystals of feldspar, well formed, and little altered.

He observed that the rocks of Chevenon, an ancient convent of Gramontin, at the distance of one league from Artonne in Auvergne, were very beautiful porphyry. Mr. Guettard found it likewise in the forest of Esterelle in Provence.

Mr. Dorthes has described more than twenty varieties of porphyry thrown up in pebbles by the Mediterranean upon our coasts, whither they are brought by the Rhone. In many of these are found transparent quartz with the prismatic form, and crystallized feldspar.

Porphyry fuses into a black globule, marked with white points.

The specific gravity of red porphyry is 27,651, and that of green, 26,760.—Brisson.

Porphyry sometimes contains schorl. Wållerius has described it "Porphir rubens, cum spatho scintillante albo, et basalto nigro."

SPECIES VII.

Jasper and Garnet.

This stone has been discovered in Iceland: the ground is a green jasper, which includes ferruginous garnets crystallized, and of a red colour.

SPECIES VIII.

Jasper and Calcedony.

The Mountain of Giants, in Bohemia, affords this stone. It has likewise been found in the Carpathian mountains, near Kaskau in Hungary. A stone has likewise been observed at Oberstein, in the Palatinate, composed of agate and jasper.

SPECIES IX.

Jasper and Quartz.

This compound stone, called *Saxum Sibericum* by Linnæus, has been found in Siberia, and also near Stuttgart in the Dutchy of Wirtemberg.

SPECIES X.

Jasper, Quartz, and Feld Spar.

This stone is found in the environs of Geneva. Its ground is a jasper, or rather a petro-silex, black, opaque, and very hard. This matrix is interspersed with small rectangular crystals of white feld spar, and rounded grains of transparent quartz. Mr. De Saussure, who has described this species, places it among the porphyries.

SPECIES XI.

Schorl, Garnet, and Tourmaline.

Mr. Muller has discovered in Schneeberg, a mountain of the territory of Sterzing in Tyrol, a rock of this kind, containing large crystals of tourmaline, which include small crystallized garnets, transparent, and of a red colour.

Mr. Ferber affirms that he found between Faistriz and Carnowitz in Stiria, detached pieces of green schorl, which inclose large red garnets: he adds, that this schorl is sometimes scaly, and of a micaceous texture.

Mr. de Saussure has found in the environs of Geneva, stones worn round by water, which were composed of schorl in the mass, and garnet.

The Mediterranean Sea throws up on our coast many varieties of rounded pebbles of porphyry, which have schorl for their basis.

GENUS VI.

Super-compound Stones, or such as result from the Mixture and Re-union of several different Genera.

SPECIES I.

Petrosilex, Alumine, and Calcareous Spar.

This stone is found at Schneeberg in Saxony.

SPECIES II.

Clay, Steatites, and Calcareous Spar.

This species, as well as the two following, are comprised under the name of Saxa Glandulosa. The steatites, the spar, and the other substances are dispersed in the matter which forms the ground of this rock.

SPECIES III.

Clay, Zeolite, Schorl, and Calcareous Spar.

SPECIES IV.

Clay, Serpentine, and Calcareous Spar.

SPECIES V.

Serpentine, Mica, and Calcareous Spar.

Mr. Ferber has described this last species under the name of Polzevera; a denomination suggested to him by the place where it is found. See his Letters on Italy.

SPECIES VI.

Serpentine, Schorl, and Calcareous Stone.

This stone surrounds the veins of the mine of St. Simon and Jude, at Dognasta, in the Bannat of Temesward: it is likewise found in the copper mines of Saska; and at Hoferschlag, near Schemnitz, in Lower Hungary.

SPECIES VII.

Steatites, Mica, and Garnets.

This stone is found at Handol in Jempterland, towards the north of Sweden.—Born. Ind. Foss. par. ii.

SPECIES VIII.

Steatites, Mica, and Schorl.

This stone was found at Salbury in Westmanland, a province of Sweden.—Born. Ind. Foss. par. ii.

SPECIES IX.

Garnets, Quartz, Mica, and Serpentine.

This contains a small quantity of pyrites. It is found at Pusterthal in Tyrol.—See Bruckman.

SPECIES X.

Feld Spar, Quartz, Mica, Steatites.

Several granites are formed by a mixture of this nature. Such are found at Sunneskog in Sweden, and at Guten Hoffnangsban near Altwoschitz in Bohemia: it is the *granites steatite mixtus* of Born.

SPECIES XI.

Quartz, Mica, and Clay.

This rock is the matrix of the ore of tin at Platte, and at Gottesgab in Bohemia.

SPECIES XII.

Quartz, Clay, and Steatites.

This is found at Mount St. Gothard in Switzerland.

Concerning the Diamond.

The Diamond forms an appendix to the history of stones. Its combustibility is a character which prevents its being assimilated to any known species.

The diamond was long considered as the hardest and most ponderous of stones, as well as the only one which did not cause a double refraction; but subsequent observations have destroyed these early notions. The adamantine spar appears to equal it in hardness; the oriental ruby, and the jargon of Ceylon, are more ponderous; and the oriental precious stones exhibit one refraction only, as does likewise the phosphoric spar.

This precious stone is found on the coast of Coromandel, and principally in the kingdoms of Golconda and Visapour. The earth which serves as its gangue is red, ochreous, and soils the fingers.

The general process of exploring the diamond mines or earths, consists in mixing the earth with water, after which the fluid is poured off, and the sand which remains at the bottom is dried by the strong heat of the sun.—See the memoirs of the Comte Marechal.

Other naturalists inform us that, when the earths have been washed; the residue is left to dry, and is sifted in baskets made for the purpose. The workmen afterwards seek for the diamonds with their hands.

Diamonds in their native state are covered with two crusts; the one earthy, and the other sparry.—Romé de Lisle.

When lapidaries undertake to work them, they are obliged to find the grain of the stone, in order to split or

cleave the diamond. If the fracture be not uniform, they call the stone a *diamond of nature*. The hardness of the diamond is such, that it resists the most highly polished steel; which circumstance renders it necessary to attack it by diamond powder.

The manner or form in which diamonds are cut, distinguishes them into rose diamonds, and brilliants, or brilliant diamonds. The brilliant diamond is cut into facets on both sides. The variety of forms given to these facets, and their different inclinations with respect to each other, multiply the refractions, and contribute to afford those reflections, and streams of pure and vivid light, which characterize the diamond.

The diamond is divided into two kinds; the oriental diamond, and the Brazilian diamond.

The oriental diamond crystallizes in octahedrons, and exhibits all the varieties of this primitive form.

The Brazilian diamond crystallizes in dodecahedrons. It is neither so hard, so heavy, so perfect, nor so valuable, as the oriental diamond.

The colourless diamond has a specific gravity which is in proportion to that of water as 35,212 to 10,000. Mr. Brisson has derived this specific gravity from an experiment on the *Pitt* diamond of the French crown. A cubic foot of this diamond would weigh two hundred and forty-six livres, seven ounces, five gross, sixty-nine grains.

The diamond is sometimes coloured green, violet, black, &c. The green are the most esteemed, because they are the most scarce. The weight of coloured diamonds is more considerable than that of the white diamond; because it is augmented by the weight of the colouring principle, which is of a metallic nature.

The brilliancy, hardness, and scarcity of the diamond have preserved it in the most extravagant degree of estimation. A diamond is said to be of a fine water when it presents no defect or spot; and the price is proportioned to its purity.

When a diamond is without fault, its value is estimated according to its weight; which is determined or divided into carats, each carat being equivalent to about four grains.

The most beautiful diamonds hitherto known are—1. The two in the crown of the King of France; one of which is the Grand Sancy, weighing one hundred and six carats; and the other the Pitt, which weighs seven gross, twenty-five grains and one-sixteenth. It is fourteen lines long, thirteen and a half broad, and nine and one-third thick. 2. The diamond which at present belongs to the Czarina weighs seven hundred and seventy-nine carats. The Empress purchased it in 1772 for twelve tons of gold (100,000 florins), and granted a pension of four thousand rubles to the seller. It is pretended that this fine diamond was one of those which ornamented the eyes of the famous statue Scheringham, which has eight eyes and four heads; and that it was carried off by a French deserter who had procured himself to be appointed as a guard to the temple of Brama. This diamond was at first sold for fifty thousand livres, afterwards for about four hundred thousand livres, and was at length purchased by the Empress of Russia.

The combustibility of the diamond is a phenomenon sufficiently interesting to induce us to give a faithful extract of the principal experiments which have served to advance our knowledge upon this subject.

Boyle observed, long since, that the diamond, exposed to a violent fire, emitted acrid vapours.

The Emperor Francis the First caused crucibles to be exposed to a reverberatory fire for twenty-four hours, into which vessels the value of six thousand florins in diamonds and rubies were put. The diamonds disappeared, but the rubies were not altered. These experiments were repeated with great expense; and it was ascertained that the diamond lost its polish, scaled off, and was dissipated.

The Great Duke of Tuscany, in 1694, caused experiments to be made by Mr. Averoni and Targioni, by the mirror of Tschirnausen, and it was found that the diamonds disappeared in a few minutes.

In 1772, these experiments were resumed by the skilful chemists of Paris—Darcet, the Comte de Laraguais, Cadet, Lavoisier, Mitouard, Macquer, &c. The details of the interesting experiments made on this subject may be seen in the volumes of the Academy of Sciences, and the *Journaux de Physique* of that year. We shall simply relate the results.

1. Messrs. Darcet and the Comte de Laraguais proved that the diamond is volatilized in balls of porcelain.

2. Mr. Macquer took notice that the diamond dilated and swelled up; and that a blue flame was observable on its surface during the combustion.

3. Messrs. Lavoisier and Cadet proved, that the combustion of diamonds in closed vessels ceased as soon as the oxigene was destroyed; and that the diamond did not burn but in proportion to the oxigene present, like all other combustible substances. The jewellers, who expose their diamonds to very violent fires to render them colourless, are careful to wrap them up in such a manner as to secure them from the contact of air.

Mr. De Saussure burned a diamond by the blow-pipe: Mr. Lavoisier has proved that, when it is exposed to the burning glass, a dust arises which precipitates lime-water.

The diamond is therefore a combustible substance, which burns in the same manner as other bodies. This strict and accurate consequence is deduced from all the experiments which can be imagined to acquire a perfect demonstration.

Within a few years chemists have discovered a very singular stone, to which the name of Adamantine Spar has been given by Bergmann.

It is black, and so hard that its powder may be used to cut the diamond; from which circumstance it has obtained its name.

It crystallizes in hexahedral or six-sided prisms, two of which are large and four small.

Its specific gravity is 38,732 with respect to water, which is assumed at 10,000. See Brisson.—The cubic foot weighs two hundred and seventy-one livres, one ounce, seven gross, sixty three grains.

The most violent fire produces only a slight softening of this spar, according to the experiments of Mr. Lavoisier.

The analysis made by Mr. Klaproth of this stone, has exhibited a peculiar earth, which is suspected to be likewise one of the principles of precious stones, &c.

GENERAL VIEWS

RESPECTING

The Decompositions and Changes to which the Stony Part of our Globe has been subjected.

IF it were permitted to man to follow, during several ages, the various changes which are produced on the surface of our globe by the numerous agents that alter it, we should at this time have been in possession of the most valuable information respecting these great phenomena : but thrown, as we are, almost by accident, upon a small point of this vast theatre of observation, we fix our attention for a moment upon operations which have employed the works of nature for ages ; and we are unable either to perceive or to foretel the results, because several ages are scarcely sufficient to render the effects or changes perceptible. Nature never ceases to exist : her activity has been coeval with the existence of matter ; her operations are not circumscribed within limited times ; she disposes of whole ages in the arrangement of her combinations ; while man can command no more than a few instants, and himself disappears at the moment wherein he has proceeded so far as to connect a few facts together. Hence, no doubt, it arises, that nature is incomprehensible in some of her operations, and inimitable in all those which require a long series of time.

It must be allowed that those men who, by the mere efforts of their imagination, have endeavoured to form ideas respecting the construction, and the great phenomena of this globe, have numerous titles to our indulgence. In their proceedings we behold the efforts of genius, tormented with the desire of acquiring knowledge, and irritated at the prospect of the scanty means which nature has put in its power : and when these naturalists, such as Mr. De Buffon, have possessed the power of em-

bellishing their hypotheses with every ornament which imagination and eloquence can furnish, either as instruments of illusion or entertainment, we ought to consider ourselves indebted to them.

For our part, we shall confine ourselves to exhibit a few ideas respecting the successive decompositions of our planet, and shall endeavour to avoid every departure from observation and matter of fact.

The slightest observation shews us that living beings are kept up and perpetuated only by successive decompositions and combinations. A slight view of the mineral kingdom exhibits the same changes; and our globe, in all its productions, presents continual modifications, and a circle of activity, which might appear incompatible with the apparent inertia of lithologic products.

In order to arrange our ideas with greater regularity, we may consider this globe in two different states. We will first examine the primitive rock which forms the nodulè or central part. This appears to contain no germ of life, includes no remains or part of any living being, and from every circumstance appears to have been of primitive formation, anterior to the creation of animated or vegetating bodies. We shall pursue the various changes which are daily produced by the destructive action of such agents as alter or modify this substance.

We shall then proceed to examine what stones have been successively placed upon this, and what are the decompositions to which these secondary rocks have been subjected.

1. The observations of naturalists all unite to prove, that the central part of the globe consists of the stone known by the name of Granite. The profound excavations which the art of man, or currents of water, have made in the surface of our planet, have all uncovered this rock, and have been incapable of penetrating lower: we may therefore consider this substance as the nucleus of the globe; and upon this substance it is that all matters of posterior formation rest.

Granite exhibits many varieties in its form, composition, and disposition; but it in general consists of an assemblage of certain siliceous stones, such as quartz, schorl, feld spar, mica, &c.; and the more or less considerable

magnitude of these elements of granite, has caused it to be divided into coarse-grained granite, and fine-grained granite.

It appears to me that there is no denying but that these rocks owe their arrangement to water: and if we may be permitted to recur, by an effort of the imagination*, to that epocha in which, according to sacred and profane historians, the water and earth were confounded, and the confused mixture of all principles formed a chaos, we shall see that the laws of gravity inherent in matter must have carried it down, and necessarily produced the arrangement which observation at present exhibits to us. The water, as the least heavy, must have purified itself, and arisen to the surface by a filtration through the other materials: while the earthy principles must have precipitated, and formed a mud, in which all the elements of stones were confounded. In this very natural order of things, the general law of affinities, which continually tends to bring together all analogous parts, must have exerted itself with its whole activity upon the principles of this almost fluid paste; and the result must have been a number of bodies of a more definite kind, in crystals more or less regular: and from this muddy substance, in which the principles of the stones were confounded that compose the granite, a rock must have been produced, containing the elementary stones all in possession of their distinct forms and characters. In this manner it is that we observe salts of very different kinds develop themselves in waters which hold them in solution; and in this manner it still happens that crystals of spar and gypsum are formed in clays which contain their component parts.

It may easily be conceived that the laws of gravitation must have influenced the arrangement and disposition of the products. The most gross and heavy bodies must have fallen, and the lightest and most attenuated sub-

* This is the first and the last supposition in which I shall indulge myself. It is a conjecture, however, which is indifferent with respect to the basis of the subject itself; since it relates only to an hypothesis respecting the manner in which a rock might be formed that at present exists, and whose decompositions alone can form the subject of our observations.

stances must have arranged themselves on the surface of the foregoing : and this it is which constitutes the primitive schisti, the gneis, the rocks of mica, &c. which commonly repose upon masses of coarse-grained granite.

The disposition of the fine-grained granite in strata or beds, appears to me to depend on this position, and the fineness or tenuity of its parts. Being placed in immediate contact with water, this fluid must naturally have influenced the arrangement which it presents to us ; and the elements of this rock being subjected to the effect of waves, and the action of currents, must have formed strata.

The rocks of granite being once established as the nucleus of our globe, we may, from the analysis of its constituent principles, and by attending to the action of the various agents capable of altering it, follow the degradations to which it has been subjected, step by step.

Water is the principal agent whose effects we shall examine.

This fluid, collected in the cavity of the ocean, is carried by the winds to the tops of the most elevated mountains, where it is precipitated in rain, and forms torrents, which return with various degrees of rapidity into the common reservoir.

This uninterrupted motion and fall must gradually attenuate and wear away the hardest rocks, and carry their pulverulent parts to distances more or less considerable. The action of the air, and varying temperatures of the atmosphere, facilitate the attenuation and the destruction of these rocks. Heat dries their surface, and renders it more accessible and more penetrable to the water which succeeds ; cold divides them, by freezing the water which has entered into their texture ; the air itself affords the carbonic acid, which attacks the lime-stone, and causes it to effloresce ; the oxigene unites to the iron, and calcines it : insomuch that this concurrence of causes favours the disunion of principles ; and consequently the action of water, which clears the surface, carries away the products of decomposition, and makes preparation for a succeeding process of the same nature.

The first effect of the rain is therefore to depress the mountains. But the stones which compose them must

resist in proportion to their hardness; and we ought not to be surprised when we observe peaks which have braved the destructive action of time, and still remain to attest the primitive level of the mountains which have disappeared. The primitive rocks, alike inaccessible to the injury of ages as to the animated beings which cover less elevated mountains with their remains, may be considered as the source or origin of rivers and streams. The water which falls on their summits, flows down in torrents by their lateral surfaces. In its course it wears away the soil upon which it incessantly acts. It hollows out a bed, of a depth proportioned to the rapidity of its course, the quantity of its waters, and the hardness of the rock over which it flows; at the same time that it carries along with it portions and fragments of such stones as it loosens in its course.

These stones, rolled along by the water, must strike together, and break off their projecting angles: a process that must quickly have afforded those rounded flints which form the pebbles of rivers. These pebbles are found to diminish in size, in proportion to the distance from the mountain which affords them; and it is to this cause that Mr. Dorthes has referred the disproportionate magnitude of the pebbles which form our ancient worn stones, when compared with those of modern date: for the sea extending itself formerly much more inland, in the direction of the Rhone, the stones which it received from the rivers, and threw back again upon the shores, had not run through so long a space in their beds as those which they at present pass over. Thus it is that the remains of the Alps, carried along by the Rhone, have successively covered the vast interval comprised between the mountains of Dauphiny and Vivarais; and are carried into our seas, which deposite them in small pebbles on the shore.

The pulverulent remains of mountains, or the powder which results from the rounding of these flints, are carried along with greater facility than the flints themselves: they float for a long time in the water, whose transparence they impair; and when these same waters are less agitated, and their course becomes slackened, they are deposited in a fine and light paste, forming beds more or less thick, and of the same nature as that of the rocks to

which they owe their origin. These strata gradually become drier by the agglutination of their principles; they become consistent, acquire hardness, and form siliceous clays, silex, petrosilex, and all the numerous class of pebbles which are found dispersed in strata, or in banks, in the ancient beds of rivers.

Mr. Pallas has observed the transition of clay to the state of silex in the brook of Sunghir, near Wolodimir. Mr. J. W. Baumer has likewise observed it in Upper Hesse.

The mud is much more frequently deposited in the interstices left between the rounded flints themselves, which intervals it fills, and there forms a true cement that becomes hard, and constitutes the compound stones known by the name of pudding-stones and grit-stones; for these two kinds of stone do not appear to me to differ but in the coarseness of the grain which forms them, and the cement which connects them together.

We sometimes observe the granite spontaneously decomposed. The texture of the stones which form it has been destroyed; the principles or component parts are disunited and separated, and they are gradually carried away by the waters. I have observed near Mende, towards Castlenouvel, the most beautiful kaolin on the surface of a granite, in a state of decomposition; and this same rock is decomposed in several other parts of our province. It appeared to me that the feldspar was particularly subject to be altered the first.

Most siliceous stones, formed by the deposition of fluviatile waters, and hardened by the lapse of time, are easily subjected to a second decomposition. Iron is the principal agent of these secondary alterations; and its calcination, determined by air or water, produces a disunion of principles. Nature may be observed in this process, by an attentive examination of such alterations as gun flints, variolites, porphyries, jaspers, and the like, are subjected to.

The decomposition of flints, calcedonies, agates, and generally all stones of this kind which possess a certain degree of transparence, appears to me to be referable to the volatilization of the water, which forms one of their principles, and is the cause of their transparency.

These stones may be considered as commencements of crystallization; and, when the water is dissipated, they effloresce after the manner of certain neutral salts. Hence it arises that the decomposition is announced by opacity, a white colour, loss of consistence and hardness; and terminates by forming a very attenuated powder, sometimes of extreme whiteness. It is this decomposition, more particularly, which forms clays.

There are flints whose alterations form effervescent marls. These do not appear to me to be of the nature of primitive rocks: they have the same origin as the calcareous stones, from which they differ only in consequence of a very considerable proportion of clay. The stones which we so abundantly find of this nature around us, among calcareous decompositions, may be considered as of this kind.

Water filtrating through mountains of primitive rock, frequently carries along with it very minutely divided particles of quartz; and proceeds to form, by deposition, stalactites, agates, rock crystal, &c.

These quartzose stalactites differently coloured, are of a formation considerably analogous to that of calcareous alabasters; and we perceive no other difference between them than that of their constituent parts.

II. Thus far we have exhibited, in a few words, the principal changes, and various modifications, to which the primitive rocks have been subjected. We have not yet observed either germination or life; and the metals, sulphur, and bitumens, have not hitherto presented themselves to our observation. Their formation appears to be posterior to the existence of this primitive globe; and the alterations and decompositions which now remain to be inquired into, appear to be produced by the class of living or organized beings.

On the one hand, we behold the numerous class of shell animals, which cause the stony mass of our globe to increase by their remains. The spoils of these creatures, long agitated and driven about by the waves, and more or less altered by collision, form those strata and banks of limestone, in which we very often perceive impressions of those shells to which they owe their origin.

On the other hand, we observe a numerous quantity of vegetables that grow and perish in the sea; and these

plants likewise, deposited and heaped together by the currents, form strata, which are decomposed, lose their organization, and leave all the principles of the vegetable confounded with the earthy principle. It is to this source that the origin of pit-coal, and secondary schistus, is usually attributed; and this theory is established on the existence of the texture of decomposed vegetables very usually seen in schisti and coal, and likewise on the presence of shells and fish in most of these products.

It appears to me that the formation of pyrites ought to be attributed to the decomposition of vegetables: it exists in greater or less abundance in all schisti and coal. I have found a wooden shovel buried in the depositions of the river De Ceze, converted into jet and pyrites. The decomposition of animal substances may be added to this cause: and it appears to me to be a confirmation of these ideas, that we find many shells passed to the state of pyrites.

Not only the marine vegetables form considerable strata by their decomposition; but the remains of those which grow on the surface of the globe, ought to be considered among the causes or agents which concur in producing changes upon that surface.

We shall separately consider how much is owing to each of these causes; and shall follow the effects of each, as if that cause alone were employed in modifying and altering our planet.

1. The calcareous mountains are constantly placed upon the surface of the primitive mountains; and though a few solitary observations present a contrary order, we ought to consider this inversion and derangement as produced by shocks which have changed the primitive disposition. I must observe also that the disorder is sometimes merely apparent; and that some naturalists of little information have described calcareous mountains as inclining beneath the granite, because this last pierces, as it were, through the envelope, rises to a greater height, and leaves at its feet, almost beneath it, the calcareous remains deposited at its base.

Sometimes even the lime-stone fills to a very great depth the crevices or clefts formed in the granite. I have seen in Gevaudan, towards Florac, a profound cavity in the granite filled with calcareous stone. This vein is known to

possess a depth of more than one hundred and fifty toises, with a diameter of about two or three.

It likewise happens frequently enough that such waters as are loaded with the remains of the primitive granite, heap them together, and form secondary granites, which may exist above the calcareous stone.

These calcareous mountains are decomposed by the combined action of air and water; and the product of their decomposition sometimes forms chalk or marl.

The lightness of this earth renders it easy to be transported by water; and this fluid, which does not possess the property of holding it in solution, soon deposits it in the form of gurns, alabasters, stalactites, &c. Spars owe their formation to no other cause. Their crystallization is posterior to the origin of calcareous mountains.

Waters wear down and carry away calcareous mountains with greater ease than the primitive mountains; their remains being very light, are rolled along, and more or less worn. The fragments of these rocks are sometimes connected by a gluten or cement of the same nature; from which process calcareous grit and breccias arise. These calcareous remains formerly deposited themselves upon the quartzose sand; and the union of primitive matter, and secondary products, gives rise to a rock of a mixed nature, which is common in our province.

2. The mountains of secondary schistus frequently exhibit to us a pure mixture of earthy principles, without the smallest vestige of bitumen. These rocks afford, by analysis, silex, alumine, magnesia, lime in the state of carbonate, and iron; principles which are more or less united, and consequently accessible in various degrees to the action of such agents as destroy the rocks hitherto treated of.

These same principles when disunited, and carried away by waters, give rise to a great part of the stones which we have comprised in the magnesian genus. The same elements, worn down by the waters, and deposited under circumstances proper to facilitate crystallization, form the schorls, tourmaline, garnets, &c.

We do not pretend by this to exclude and absolutely reject the system of such naturalists as attribute the formation of magnesian stones to the decomposition of the primitive rocks. But we think that this formation cannot

be objected to for several of them, more especially such as contain magnesia in the greatest abundance.

It frequently happens that the secondary schisti are interspersed with pyrites; and, in this case, the simple contact of air and water facilitates their decomposition. Sulphuric acid is thus formed, which combines with the various constituent principles of the stone; whence result the sulphates of iron, of magnesia, of alumine, and of lime, which effloresce at the surface, and remain confounded together. Schisti of this nature are wrought in most places where alum works have been established; and the most laborious part of this undertaking consists in separating the sulphates of iron, of lime, and of magnesia from each other, which are mixed together. Sometimes the magnesia is so abundant that its sulphate predominates: I have seen mountains of schistus of this nature. The sulphate of lime being very sparingly soluble in water, is carried away by that liquid, and deposited to form gypsum; while the other more soluble salts remaining suspended, form vitriolic mineral waters.

The pyritous schisti are frequently impregnated with bitumen, and the proportions constitute the various qualities of pit-coal.

It appears to me that we may lay it down as an incontestable principle, that the pyrites is abundant in proportion as the bituminous principle is more scarce. Hence it arises, that coals of a bad quality are the most sulphureous, and destroy metallic vessels by converting them into pyrites. The focus of volcanos appears to be formed by a schistus of this nature; and in the analyses of the stony matters which are ejected we find the same principles as those which constitute this schistus. We ought not therefore to be much surprised at finding schorls among volcanic products; and still less at observing that subterranean fires throw sulphuric salts, sulphur, and other analogous products out of the entrails or the earth.

3. The remains of terrestrial vegetables exhibit a mixture of primitive earths more or less coloured by iron: we may therefore consider these as a matrix in which the seeds of all stony combinations are dispersed. The earthy principles assort themselves according to the laws of their affinities; and form crystals of spar, of plaster, and

even the rock crystals, according to all appearance: for we find ochreous earths in which these crystals are abundantly dispersed; we see them formed almost under our eyes. I have frequently observed indurated ochres full of these crystals terminating in two pyramids.

The ochreous earths appear to me to deserve the greatest attention of naturalists. They constitute one of the most fertile means of action which nature employs; and it is even in earths nearly similar to these that she elaborates the diamond, in the kingdoms of Golconda and Visapour. If it were allowable to indulge in a fiction purely poetical, we might affirm that the element of fire, so far from being lost by the dispersion of the combustible principles of vegetables, becomes purified to form this precious stone so eminently combustible; that nature has been desirous of proving that the terms Destruction and Death are relative only to the imperfection of our senses; and that she is never more fruitful than when we suppose her to be at the moment of extinction.

The spoils of animals which live on the surface of the globe, are entitled to some consideration among the number of causes which we assign to explain the various changes our planet is subjected to. We find bones in a state of considerable preservation in certain places; we can even frequently enough distinguish the species of the animals to which they have belonged. From indications of this sort it is that some writers have endeavoured to explain the disappearance of certain species; and to draw conclusions from thence, either that our planet is perceptibly cooled, or that a sensible change has taken place in the position of the axis of the earth. The phosphoric salts and phosphorus which have been found, in our time, in combination with lead, iron, &c. prove that, in proportion as the principles are disengaged by animal decomposition, they combine with other bodies, and form the nitric acid, the alkalis, and in general all the numerous kinds of nitrous salts.

INDEX.

A.			
	Page.		Page.
ACID , general properties of	142	Carbonate of Potash	152
— Carbonic	140	— of Soda	153
— Sulphuric	156	— of Ammoniac	154
— Nitric	166	— of Lime	219
— Muriatic	179	— of Barytes	241
— Oxymuriatic	183	— of Magnesia	245
— Nitromuriatic	197	— of Alumine	249
— Boracic	199	Chemistry, method of studying	58
— Fluoric	235	Chrysolite	279
Affinity of aggregation	43	Chrysoprase	300
Affinity of composition	45	Carnehan	291
Agustina	218	Crucibles	36
Agate	288	Crystallization	50
Asbestos	260		
Alkali volatile	138	D.	
Alkalis	130	Decomposition, laws of	47
Alumine	215	Diamond	322
Amianthus	261	Distilling vessels	34
Amethyst	286	Distillation of water	124
Atmospheric air	116		
Attraction	42	E.	
		Elementary substances	64
B.		Emerald	279
Balances	40	Evaporation	76
Barytes	213	Evaporatory vessels	31
Basaltes	295		
Beryl	279	F.	
Blood, red color of	111	Feld Spar	305
Borate of Potash	202	Fire	65
— of Soda	ibid.	Flint	287
— of Ammoniac	206	Fluate of Lime	234
		Frigorific mixtures	75
C.		Fulminating powder	177
Calcedony	290	Furnaces	88
Carbone	88		30 et seq.
VOL. I.		U u	

	Page		Page.
G.		Muriate of Magnesia	244
Garnet	276	N.	
Geological observations	328		
Glucina	217	Nitrate of Potash	172
Gun-powder	176	— of Soda	178
Gypsum	230	— of Ammoniac	178
		— of Lime	237
H.		— of Barytes	242
		— of Magnesia	244
Heat	66	Nitrogene Gas	114
Hornblende	269	Nitrous Gas	169
Horn Stone	270	Nitrous Oxide	179
Hyacinth	278		
Hydrogenous Gas	93	O.	
I.		Opal	289
Inflammable air	93	Oxygenous Gas	99
		Use of in Phthisis	113
J.		Oxide of Carbon	155
		Oxymuriate of Potash	187
Jasper	291	P.	
L.		Plates, explanation of	41
		Phosphate of Lime	238
Lapis Lazuli	303	Potash	131
Light	78	Pottery	265
Lime	211	Porcelain	266
Lime water	228		
Lithology	207	Q.	
Liver of sulphur	137		
Lutes	38	Quartz	286
M.		R.	
Magnesia	212	Retorts	34
Marble	222	Reagents, effects of	57
Mica	268	Rock Crystal	282
Mortar	229	Ruby	276
Mountain Cork	260	Ruby false	284
Muriate of Potash	190		
— of Soda	191	S.	
— of Ammoniac	195		
— of Lime	238	Sapphire	281, 285
— of Barytes	242	Serpentine	259

INDEX.

339

	Page.		Page.
Schorl	293	Trapp	299
Silex	216		
Solution	54	V.	
Soda	134		
Strontites	214		
Steatites	257	Vegetables exposed to light	80.
Slate	270		
Sublimation	33	W.	
Sulphur	84		
Sulphate of Potash	161	Water	118
— of Soda	162	Water in the state of Gas.	
— of Ammoniac	164	Composition of	126
— of Lime	230	Woulfe's Apparatus	38
— of Barytes	239		
— of Magnesia	240	Y.	
— of Alumine	246		
		Yttria	216
T.			
Talk	256	Z.	
Thermometers	68		
Topaz	277, 285	Zeolite	274
Tourmaline	292	Zirconia	317

